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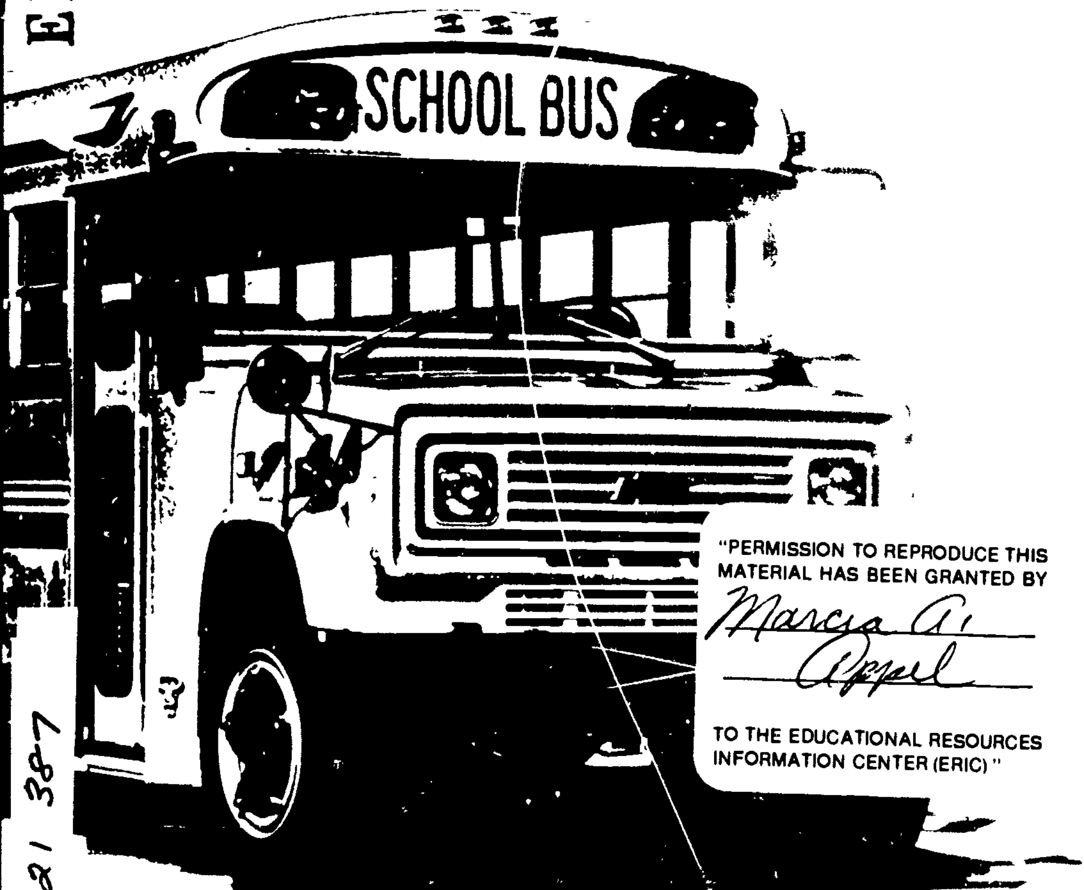
ABSTRACT

While school buses transport more passengers per trip, the rate of occupant fatalities per mile driven for school buses is one-quarter that for passenger cars. Nevertheless, the public expects school districts and other school bus operators to take all reasonable precautions to protect children as they travel to and from school. Although a variety of safety improvements have been made to school bus design and operation, further improvements are always possible. Effective April 1977, the National Highway Traffic Safety Administration issued and modified a number of federal motor vehicle safety standards to enhance the safety of school bus transportation. For post-1977 school buses weighing less than 10,000 pounds, these standards require that passenger seats be equipped with seat belts. For school buses weighing more than 10,000 pounds, the standards do not require seat belts, but instead rely on strong, well-padded, energy-absorbing seats and higher seat backs to protect passengers during a crash. Prohibiting standees and raising the minimum height of seat backs from 20 to 24 inches can improve passenger safety during crashes. Measures to improve the safety of bus loading zones include school bus driver training, stop sign arms, school bus routing, and pedestrian safety. Appendices contain details about (1) school bus accidents; (2) brief narratives of fatal school bus accidents in three states; (3) supplemental information on 26 fatal school bus accidents; (4) narratives of 13 fatal school bus accidents in Texas; and (5) cost-effectiveness analysis of school bus safety measures. (KM)

Special Report 222

IMPROVING SCHOOL BUS SAFETY



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Special Report 222

IMPROVING SCHOOL BUS SAFETY

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This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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Preface

School bus safety is a serious and sometimes controversial issue. The public expects that school districts and other school bus operators will take all reasonable precautions to protect children as they travel to and from school. Although a variety of safety improvements have been made to school bus design and operation, further improvements are always possible.

In recent years the search for further improvements to school bus safety has often focused on seat belts. Current federal standards do not require the installation of seat belts on new school buses with gross vehicle weight ratings greater than 10,000 lb, the workhorses of the nation's school bus fleet. Some individuals and organizations have argued, however, that seat belts should be required on all new school buses. A number of local school districts and one state (New York) now order seat belts as standard equipment on all school buses.

The continuing debate over seat belts on school buses led to a provision in the Surface Transportation and Uniform Relocation Assistance Act of 1987 requesting that the National Academy of Sciences investigate the

> principal causes of fatalities and injuries to school children riding in school buses and of the use of seat belts in school buses and other measures that may improve the safety of school bus transportation . . . to determine those safety measures that are most effective in protecting the safety of school children while boarding, leaving, and riding in school buses.

To conduct this study, the National Research Council, the operating agency of the National Academies of Sciences and Engineering, assembled a committee of experts in highway safety, pediatrics, school transportation, bus manufacture, occupant-restraint systems, and public policy analysis.

The committee used national and state travel data to determine the nature, frequency, and severity of school bus accidents. With staff assistance it reviewed hundreds of study reports, accident analyses, and technical articles to evaluate the likely effectiveness of measures that might improve the safety of school bus transportation. For selected measures approximate safety cost-effectiveness comparisons were developed.

Reflecting the origins of the study request, much of the study effort was devoted to seat belts and other approaches to occupant restraint.

Nevertheless, the study committee took a comprehensive view of school bus safety and addressed a broad range of safety measures, including those that might provide better protection to children as pedestrians at school bus stops and as passengers on school buses.

For occupant-restraint measures, a considerable body of research is available. Although uncertainty still remains about the effectiveness of these measures, the committee was able to use the research and prior studies to narrow the range of uncertainty. For other measures, little research and few impartial evaluation studies are available. The lack of reliable research seriously hampered the ability of the study committee to compare measures with respect to their safety cost-effectiveness. To develop approximate safety cost-effectiveness comparisons, the committee made judgments about the effectiveness of selected measures in reducing fatalities and injuries in school bus accidents. These judgments were often based more on the collective knowledge and experience of committee members than on directly relevant research. Nevertheless, the committee believes that these rough estimates of safety cost-effectiveness will be of immediate value to the federal, state, and local agencies that must continually make decisions that affect school bus safety.

The safety cost-effectiveness analyses were limited to school bus safety measures. No attempt was made to compare school bus safety measures with other, more broadly targeted highway safety measures such as changes in the design of passenger cars and highways, drunk driving laws, or driver licensing requirements. Such comparisons must be made with caution because society's willingness to invest in the safety of children is probably quite different from its willingness to invest in measures aimed at improving the safety of the population as a whole.

The committee is indebted to many individuals and organizations, both public and private, that provided data and information for the study. Local school districts reported on their experience with seat belts; individual states provided school bus accident data; and school bus and equipment manufacturers supplied cost and other information on their products. The National Highway Traffic Safety Administration made available its Fatal Accident Reporting System and offered assistance throughout the study, particularly in understanding and interpreting applicable motor vehicle safety regulations.

Individuals making presentations to the committee included Nancy Bauder, National Coalition for Seat Belts on School Buses; Suzanne Stack, National Transportation Safety Board; Charles Gauthier, National Highway Traffic

of Pupil Transportation Services; Richard Kuykendall, 3M, Inc.; John Atkinson, Insta Products, Inc.; and William Gardner, Transport Canada.

The study was performed under the overall supervision of Robert E. Skinner, Jr., Director of Special Projects. Dr. Lindsay I. Griffin III managed the study and drafted most of the report under the supervision of the committee. Thomas Menzies assisted in the analysis of accident data and developed cost information.

Special appreciation is expressed to Nancy A. Ackerman, TRB Director of Publications, and Edythe T. Crump, Senior Editor, for editing and publishing the final report, and to Frances E. Holland and Marguerite Schneider for typing the many drafts and final manuscript.

Contents

Executive Summary

Each year in the United States 10 children on average are killed while riding to and from school or school-sponsored activities in large, "Type I" school buses—buses with gross vehicle weight ratings (GVWRs) greater than 10,000 lb—which make up 80 to 85 percent of the nation's school bus fleet. Another 2 children are killed while riding in other vehicles used as school buses, and 38 children are killed in loading zones around school buses. In addition, about 480 children are seriously injured while riding in school buses, and 160 are seriously injured while boarding or leaving school buses.[1]

Although the death or injury of any child transported by school bus is a cause for concern, the safety record of school buses is good considering the amount of travel involved. In a typical year, the nation's 390,000 school buses travel nearly 4 billion mi to transport 25 million children to and from school or various school-sponsored activities. Even though school buses transport more passengers per trip, the rate of occupant fatalities per mile driven for school buses is about one-fourth that for passenger cars.[2] Nevertheless, the public expects that the federal and state governments, as well as local school districts and private school bus contractors, will continually review the safety of school bus transportation and take all reasonable precautions to protect children who travel by school bus.

Effective April 1, 1977, the National Highway Traffic Safety Administration (NHTSA) issued three new federal motor vehicle safety standards and modified four others to enhance the safety of school bus transportation. For post-1977 school buses (i.e., buses manufactured after April 1, 1977) with GVWRs of 10,000 lb or less, these standards require that passenger seats be equipped with seat belts (i.e., lap belts). For the more common Type I school buses with GVWRs greater than 10,000 lb, the standards do not require seat belts, but instead rely on strong, well-padded, energy-absorbing seats and higher seat backs to "compartmentalize" and protect passengers during a crash. NHTSA concluded that the compartmentalization requirements are adequate and that seat belts are not warranted on the larger school buses.

Other individuals and organizations, however, argue that seat belts are warranted on all school buses and that they should be installed at the time of manufacture. In the last several years a number of school districts, and one state (New York), have begun ordering seat belts as standard equipment on all new school buses.

The continuing debate over seat belts on school buses led to a provision in the Surface Transportation and Uniform Relocation Assistance Act of 1987 requesting that the National Academy of Sciences examine the causes of school bus accidents and evaluate the effectiveness of safety measures, including seat belts, that might better protect children while they are boarding, riding, and leaving school buses.

Post-1977 School Buses

The committee believes that the standards issued by NHTSA in 1977 have substantially improved the crashworthiness of school buses and have made a mode of transportation that was already quite safe even safer. All states, local school districts, and private contractors that are still operating pre-1977 school buses should replace these vehicles with post-1977 school buses as rapidly as possible. Private organizations such as church groups that purchase and operate used, pre-1977 school buses should be informed that these buses do not meet current standards for newly manufactured buses and that they should rigorously maintain these vehicles and provide safety instruction, including evacuation, for all passengers.

Seat Belts

If all large, Type I school buses operated in the United States were equipped with seat belts, one life might be saved and several dozen serious injuries avoided each year. On the basis of this estimate, the committee concludes that the overall potential benefit of requiring seat belts in large school buses is insufficient to justify a federal standard mandating installation. The funds used to purchase and maintain seat belts in the nation's fleet of school buses—more than $40 million/yr—might better be spent on other school bus safety programs and devices to save more lives and reduce more injuries. Most members of the committee believe, therefore, that states and local school districts should not be encouraged to equip new buses with seat belts. Nevertheless, some members believe that a uniform occupant-restraint policy for all motor vehicles is important enough that states and local school districts should be encouraged to equip new school buses with seat belts.

States and local school districts that choose to require seat belts in buses must ensure that all school bus passengers wear them and wear them correctly. Any program to require the use of seat belts on school buses can be effective only if it has the support of the school board, school administrators, teachers, parents, and school bus drivers.

Finally, retrofitting any large school bus with seat belts can present problems. On pre-1977 school buses, seat belts used in conjunction with the lower, less-padded seat backs typical of those buses might actually increase the severity of injuries. Consequently, seat belts should *not* be installed on buses that were manufactured before April 1, 1977. For post-1977 buses, retrofitting with seat belts is more complicated and costly than installing seat belts at the factory as original equipment, and therefore is generally not recommended.

Other Measures To Improve the Safety of School Bus Passengers During Crashes

Besides seat belts, a variety of other programs and devices that are available might better protect school bus passengers during crashes. Although it is not possible to rigorously quantify the safety benefits of these measures, the committee believes that two safety measures merit immediate action, and several others are worthy of further research, development, and evaluation.

- *Prohibit standees.* If the school bus safety standards issued by NHTSA are to be effective in reducing injuries, all passengers must be properly seated. Passengers who are out of position during a school bus crash may sustain unnecessary injuries while endangering others as they are thrown about inside the passenger compartment. The committee recommends that all states prohibit standees on school buses operated by or for public or private schools.
- *Higher seat backs.* Raising the minimum height of school bus seat backs from 20 to 24 in [as measured from the seating reference point (SRP)] would provide passengers with added crash protection, particularly for the head, at little added cost to the purchase price of a school bus. Concerns have been raised about possible interference of higher seat backs with a driver's ability to monitor student behavior and about possible noncompliance with an existing standard that addresses window emergency exits. However, two states now require higher seat backs and report no operational problems or difficulty in complying with the NHTSA standard governing emergency exits. The committee believes that any problems associated with higher seat backs can be overcome and that NHTSA should revise its standards to require that school bus seat backs be at least 24 in. above the SRP.

In addition to the standard lap belts that are currently being used in school buses in a number of school districts in the United States, three other seat and restraint systems were considered. lap bars, lap and shoulder belts, and high-backed rear-facing seats with lap belts. It is too soon to recommend any of these systems for general use; additional research and testing are needed.

To enhance and extend the structural integrity of school bus bodies, the committee recommends that NHTSA further study the feasibility of (a) improving the perimetric structure of school buses for greater side-impact protection and (b) making various body components, such as ventilation spaces and access panels, less hazardous during crashes.

Finally, to make school buses more visible and avoid nighttime accidents, NHTSA should consider the potential cost and safety effectiveness of using reflective materials on school buses and determine if minimum standards for the use of such materials are warranted.

Measures To Improve the Safety of School Bus Passengers After Crashes

Post-crash fires in school bus accidents are rare. No evidence was found that any *school* bus accident fatalities resulted from fire or smoke inhalation during the study. Nevertheless, the *church* bus crash and fire in Carrollton, Kentucky, May 14, 1988, that involved a pre-1977 bus and resulted in the deaths of 27 bus occupants serves as a grim reminder that post-crash fires can and do occur in bus accidents. Partly as a result of the Carrollton crash, both industry and government are considering measures that might make fuel systems on school buses safer (relocating the fuel tank, substituting diesel engines for gasoline engines, etc.).

Research is also progressing in the development of new materials that have the energy-absorption characteristics that are necessary for school bus seats and at the same time are fire resistant or fire retardant.

NHTSA should monitor this research to determine if and when these new materials should be required in school bus construction by federal standards for school bus construction.

NHTSA should reconsider the minimum number of emergency exits that are required on school buses. Under current standards, the number of emergency exits on school buses is independent of seating capacity. School buses with higher seating capacities should have more emergency exits. In addition, NHTSA should prohibit the installation of seats that obstruct emergency doors.

Measures To Improve the Safety of Children in School Bus Loading Zones

School bus accident data show that children are at a greater risk of being killed as pedestrians in school bus loading zones than as passengers on school buses. Of the 38 children killed each year in loading zones around school buses, two-thirds are struck by school buses. A larger share of school bus safety efforts should be directed to the loading zone.

Of the several safety programs and devices proposed to reduce the number of deaths and injuries in school bus loading zones, five should receive immediate attention. Others merit additional field testing and evaluation.

- *School bus driver training.* The requirements for school bus driver training vary considerably among the states; for example, some states do not require school bus drivers to be trained in school bus operation or pupil management before transporting children to and from school. The committee recommends that all states establish minimum criteria for school bus driver training and that all drivers receive training before transporting children.
- *Stop signal arms.* Currently, 28 states require the use of stop signal arms—stop signs with flashing red lights that extend from the left side of the school bus when it stops to load or unload students. Evaluations of this device have demonstrated its effectiveness in stopping other traffic at school bus stops. The committee recommends that NHTSA require installation of stop signal arms on all new school buses and that states and local school districts consider retrofitting older buses with stop signal arms.
- *School bus routing.* The basic principles of school bus routing are well known. These principles should be consciously applied and should not be sacrificed for operational efficiency, student convenience, or political expediency. States and local school districts should review their school bus routes annually and take all practical measures to ensure that the routes have been safely planned and are being followed as intended.
- *Pedestrian safety education.* States and local school districts are encouraged to provide behavior-based pedestrian safety education programs to children in grades K through 6. These programs should stress safe and appropriate behavior in school bus loading zones. NHTSA should complete the development of its pedestrian education program and assist the states and local school districts in their efforts to provide instruction in pedestrian safety.
- *Cross-view mirrors.* By federal standard all new school buses must be equipped with a mirror that provides the driver a view of the road immediately in front of the bus. NHTSA should reexamine this standard to determine if

current specifications for mirrors can be modified to give the driver a better view of the area in front of and immediately beside the bus.

Other measures to prevent children from being struck by their own school buses are in various stages of development. Electronic and mechanical devices to detect the presence of a child near the bus have recently come on the market. Crossing control arms that force children to cross far enough in front of the bus so that they can be seen by the driver are also now available as an option on school buses. These devices should be field tested and evaluated by NHTSA as well as by states and local school districts.

To prevent children from being struck by other vehicles in school bus loading zones, the committee recommends that states field test and evaluate the California practice of requiring the school bus driver to escort children in grades K through 8 across the street or highway when they leave a school bus. Similarly, states and local school districts are encouraged to field test external loud speaker systems that allow the driver to communicate with children who have left the bus and tell them when it is safe to cross a street or highway.

Other Findings and Recommendations

A number of the recommendations call for field testing and evaluating different school bus safety devices (e.g., with external loud speaker systems) or retaining some measures (e.g., seat belts) as options for states and local jurisdictions. Although these recommendations may encourage additional variability in the construction of school buses, the committee urges the states, in cooperation with NHTSA, to work toward more universally acceptable standards for school bus construction and equipment. Nonuniformity of standards among states adds to the cost of each school bus sold and makes the purchase of newer, safer buses more expensive.

Finally, the study was seriously hampered by a lack of reliable and valid school bus accident data and a dearth of information on the effectiveness of potential school bus safety programs and devices. The committee recommends that NHTSA work with the states, and other interested organizations, to upgrade and standardize school bus accident data collected by the states. As the quality of school bus accident data improves, these data should be used to better define why and how children are being injured in school bus accidents and to evaluate the effectiveness of various school bus safety programs and devices in reducing the number of accidents, deaths, and injuries.

Notes

1. The term *serious injury* as used in this report refers to "incapacitating" injuries that range from severe lacerations or broken limbs to quadriplegia or coma (see Chapter 3). Serious injuries are not necessarily life-threatening and most do not result in permanent disability.
2. The safety record of school buses reflects, in part, the larger size and higher center of gravity of school buses as well as safer operating conditions (e.g., more travel on weekdays during daylight hours) when compared with passenger cars.

1 Introduction

SCHOOL BUSES IN THE United States travel nearly 4 billion mi each year to transport approximately 25 million children to and from school or various school-sponsored activities. In a typical year, 10 students are killed while riding in Type I school buses with gross vehicle weight ratings (GVWRs) greater than 10,000 lb that make up the bulk of the nation's school bus fleet, and another 2 are killed while riding in other vehicles used as school buses. Altogether, 17 occupants (12 students, 5 drivers and adult passengers) are killed while riding in school buses or vehicles used as school buses (i.e., 0.5 occupant fatalities per hundred million vehicle miles traveled) (see Table 3-2, chapter 3, for further detail). By comparison, passenger cars are driven about 1.3 trillion mi each year and about 25,000 drivers and passengers are killed (i.e., 1.9 occupant fatalities per hundred million vehicle miles traveled) (Table 1-1). When it is considered that the occupancy rate for school buses is typically many times higher than that for passenger cars, the relative safety of school buses compared with passenger cars is all the more striking.

Statistics on occupant fatalities by vehicle type (Table 1-1) have led the National Highway Traffic Safety Administration (NHTSA) to declare that "school buses are the safest form of surface transportation" (NHTSA 1985, 1). Although this statement and the statistics on which it is based have been challenged (Fast 1984), it is generally agreed that school bus transportation in the United States has a good safety record.[1] Nevertheless, school bus accidents do occur, sometimes with tragic consequences. When a school bus accident occurs, public concern is heightened, and the inevitable questions are asked: Why did it happen? What would have prevented it?

To address such questions, the U.S. Congress asked the Department of Transportation in the Surface Transportation and Uniform Relocation Assistance Act of 1987 to contract with the National Academy of Sciences [Public Law 100-17, 204(a) (April 2, 1987)] to conduct a comprehensive study and investigation of the principal causes of fatalities and injuries to school children riding in school buses and of the use of seat belts in school buses and other measures that may improve the safety of school bus transportation. The purpose of the study and investigation is to determine those safety measures that are most effective in protecting the safety of school children while boarding, leaving, and riding in school buses.

TABLE 1-1 OCCUPANT FATALITIES AND FATALITY RATES BY VEHICLE TYPE (1986)

Vehicle Type	Occupant Fatalities[a]	Estimated Vehicle Miles Traveled (millions)	Occupant Fatalities per Hundred Million Vehicle Miles Traveled
Motorcycles	4,551	9,397[b]	48.4
Passenger cars	24,922	1,301,214[b]	1.9
School buses	17[d]	3,808[c]	0.5

NOTE: Vehicle occupants include drivers and passengers of all vehicles used as school buses.

[a]*Fatal Accident Reporting System 1986*, Table 1-8, p. 8 and Figure 6-21, NHTSA, U.S. Department of Transportation, p. 32.

[b]*Highway Statistics 1987*, Table VM-1, p. 177. U.S. Department of Transportation.

[c]School buses operated at public expense traveled 3,301 million vehicle miles in 1986 (*School Bus Fleet*, 38). This number was factored upward on the basis of enrollment to include private school transportation.

[d]Five-year average based on 1982–1986 data (see Table 3-1 in Chapter 3).

Legislative History

In the Highway Safety Act of 1966, Congress called for the development of state highway safety programs to reduce the number of traffic-related deaths and injuries that were occurring throughout the nation [Public Law 89-564, 402(a) (September 9, 1966)]:

> Each State shall have a highway safety program approved by the Secretary, designed to reduce traffic accidents and deaths, injuries, and property damage resulting therefrom. Such programs shall be in accordance with uniform standards promulgated by the Secretary.

Pursuant to this legislation, the secretary issued 18 highway safety program standards, including Highway Safety Program Standard (HSPS) 17, Pupil Transportation Safety (NHTSA 1974). This standard discusses the administration of school bus programs, the operation and maintenance of school buses, and the training of school bus drivers. HSPS 17 is no longer a mandatory federal standard imposed on a state's safety program; it is now a guideline

[Public Law 100-17, 206(a) (April 2, 1987)]. NHTSA states that "the intent of these guidelines is to provide the latest state-of-the-art thinking on specific highway safety issues rather than place requirements on a program" (NHTSA 1985, 5).

In the National Traffic and Motor Vehicle Safety Act of 1966, Congress authorized the U.S. Department of Transportation (DOT) to issue minimum safety standards for new motor vehicles (including school buses) manufactured for sale in the United States [Public Law 89-563 (September 9, 1966)]. Congress amended the act in 1974 and specifically directed the Secretary of Transportation to issue minimum performance standards for school buses in the following areas [Public Law 93-492, 202 (October 27, 1974)]:

- Emergency exits;
- Interior protection for occupants;
- Floor strength;
- Seating systems;
- Crashworthiness of body and frame, including protection against rollover hazards;
- Vehicle operating systems;
- Windows and windshields; and
- Fuel systems.

The DOT issued three new Federal Motor Vehicle Safety Standards (FMVSS), effective April 1, 1977, to enhance the safety of school bus occupants:

- FMVSS 220, School Bus Rollover Protection;
- FMVSS 221, School Bus Body Joint Strength; and
- FMVSS 222, School Bus Passenger Seating and Crash Protection.

In addition, four existing standards were modified to improve school bus safety:

- FMVSS 105, Hydraulic Brake Systems, extended to include school buses (April 1, 1977);
- FMVSS 111, Rearview Mirrors, modified to require cross-view mirrors that provide drivers better vision immediately in front of the bus (February 26, 1977);
- FMVSS 217, Bus Window Retention and Release, revised to address minimum performance requirements for emergency exits on school buses (April 1, 1977); and

• FMVSS 301, Fuel System Integrity, revised to address the fuel systems on all school buses, including buses with GVWRs greater than 10,000 lb (April 1, 1977).

In 1976 Congress sought additional information on school bus safety. The National Traffic and Motor Vehicle Safety Act of 1966 was amended to request the Secretary of Transportation to further review the safety of school bus transportation and to consider the benefits that might be realized from the use of seat belts. or other occupant restraint systems, on school buses [Public Law 94-346 (July 8, 1976)].

In responding to Congress, the Secretary of Transportation expressed the belief that a regulation to require seat belts on school buses with GVWRs greater than 10,000 lb was not warranted. "Given the present state of knowledge, compartmentalization, coupled with other passive concepts, is preferred to the installation of seat belts as a reasonable and practical means for providing passenger protection within the bus itself" (NHTSA 1977, VII-3).

For school buses with GVWRs greater than 10,000 lb, FMVSS 222, School Bus Passenger Seating and Crash Protection (effective April 1, 1977), is intended to provide the passive protection to which the Secretary referred. The standard requires that school bus seats be well padded and equipped with high seat backs to better contain or compartmentalize passengers in the event of a crash. For school buses with GVWRs less than or equal to 10,000 lb, seat belts (lap belts) became required equipment.

Seat Belts on School Buses

In the 1987 legislation that requested the National Academy of Sciences to study the causes of school bus accidents and to evaluate measures that might reduce the deaths and injuries resulting from such accidents, one measure was specifically cited: seat belts.

The use of seat belts on school buses has been widely debated in recent years. The state of New York now requires that all school buses manufactured after June 30, 1987, and operated within its jurisdiction be equipped with seat belts (New York Laws 1986).

Federal regulations do not currently require that passenger seats in school buses with GVWRs greater than 10,000 lb be equipped with seat belts. NHTSA (1985, 1), the federal agency that has the authority to issue regulations for new motor vehicles, continues to believe that

> the occupant protection required in school buses manufactured after April 1, 1977, plus the inherent safety of a highly recognizable vehicle that travels on a regular route, provide a high level of safety.
>
> In view of the effectiveness of the current safety standards, and the excellent safety record of school buses generally, we do not believe that a Federal requirement for safety belts in large school buses is warranted.
>
> Small, van-type school buses (under 10,000 pounds gross weight) are required to have safety belts for all occupants as standard equipment. The agency believes that safety belts are necessary and effective in providing occupant protection in those vehicles because of their similarity to cars, and we encourage all passengers to wear their belts whenever the vehicles are in motion.
>
> It is important to emphasize that the Federal standards specify the minimum safety requirements applicable to school buses. *Nothing prohibits a State or local jurisdiction from purchasing buses equipped with safety belts.* [Emphasis added.]

Following a series of school bus crash tests conducted by Transport Canada, the Canadian government concluded in January 1985 that in frontal collisions, post-1977 school buses (i.e., buses manufactured after April 1, 1977) provide good occupant protection and that the use of seat belts may result in more severe head and neck injuries to passengers (Farr 1985, 7). After conducting in-depth investigations of 43 accidents involving post-1977 school buses with GVWRs greater than 10,000 lb, the National Transportation Safety Board (NTSB) concluded in March 1987 that the use of seat belts would probably not have reduced the fatalities or the severe injuries observed in its study (NTSB 1987, 98). Neither the Canadian government nor NTSB believes that seat belts (i.e., lap belts) are warranted on post-1977 buses. Of the organizations that have considered the use of seat belts on school buses, the National Safety Council (NSC) supports NHTSA's position, as did the 1985 National School Bus Standards Conference (NSC 1986, NSBSC 1985).

Many other organizations believe that post-1977 school buses should be equipped with seat belts to maximize occupant protection. Among the organizations advocating the installation of seat belts in buses with GVWRs greater than 10,000 lb are the following:

- American Medical Association (AMA 1987),[2]
- Physicians for Automotive Safety (PAS 1980),
- National Coalition for Seatbelts on School Buses (NCSSB) (presentation by Nancy Bauder, President of NCSSB, to the Committee on the Study to Identify Measures That May Improve the Safety of School Bus Transportation),
- American Academy of Pediatrics (AAP 1984),

- Society for Adolescent Medicine (SAM 1985), and
- American College of Emergency Physicians (ACEP 1987).[3]

Advocates of seat belts in school buses offer the following arguments in support of seat belt regulations.

1. If a crash should occur, the use of seat belts will reduce the probability of death (and the severity of injuries) to children correctly seated in post-1977 buses. Furthermore, the use of seat belts may keep children in their seats and thereby further reduce deaths of and injuries to "out-of-position" passengers, for example, children who may have put their head or arms outside the window or children who are out of their seats when a collision occurs.
2. Seat-belt use will improve passenger behavior and reduce driver distractions. Reductions in driver distractions may translate into accidents avoided.
3. Use of seat belts in school buses will have a "carryover" effect—children will be encouraged to use seat belts when riding in other vehicles.
4. The cost of installing lap belts in buses is minimal, no more than $1,000 to $2,000 per bus.

Others raise several objections to a policy that requires belts to be installed on all new buses.

1. School bus collisions that result in deaths or serious injuries to passengers are often catastrophic accidents that involve tractor trailer trucks, trains, massive fixed objects, and so forth. In these accidents seat belts are of little or no benefit and, in some cases (e.g., fires), they may be harmful. In less catastrophic accidents, current standards (post-1977) provide adequate school bus passenger protection.
2. Installation of seat belts in school buses does not guarantee seat belt use. If seat belts are not used, they cannot reduce deaths and injuries if a collision occurs. If drivers are required to ensure that the seat belts of all children are correctly buckled, driver distractions will increase.
3. If drivers do not insist that children use their belts, then any potential carryover effect of using seat belts in buses will be lost. Indeed, if children ride unbelted in belt-equipped buses, the message they learn, and the behavior they carry over to a passenger car, will be harmful.
4. Finally, because the safety record of school buses is already good, deaths and injuries to school bus passengers are rare. Spending $1,000 to $2,000 per bus for seat belts would not be cost effective; that is, the money could be better spent on other safety measures.

Additional Measures To Enhance School Bus Safety

Although installation of seat belts is the measure most discussed to enhance school bus safety, a variety of other programs and devices were proposed and reviewed during this study. These programs and devices fall into two groups: (a) measures that enhance the safety of school bus passengers during a crash and (b) measures that prevent children outside of school buses from being struck by their own bus or by other vehicles.

Specific programs and devices considered to enhance the protection of school bus passengers include

- Seat belts (lap belts),
- Lap bars,
- Lap and shoulder belts,
- Rear-facing seats,
- Higher seat backs,
- Prohibiting standees,
- Structural integrity of the bus body,
- Emergency exits and evacuation procedures,
- Fuel system integrity and material flammability, and
- Reflective markings on school buses.

Specific programs and devices considered to enhance the safety of children in school bus loading zones include

- Driver training,
- Pupil education,
- School bus monitors or driver escorts,
- School bus routing,
- Cross-view mirrors,
- Stop signal arms and strobe lights, and
- Electronic and mechanical sensors and barriers.

Definitions

The term school bus as used in this report is defined as a vehicle operated by a public or private school, or a private contractor, for the purpose of transporting children (through grade 12) to and from school or other school-sponsored activities. Vehicles that fit this description are externally identifiable as school buses, typically by color (yellow) and lettering that identifies the school or school district served by the bus. Vehicles that are *structurally* recognizable as school buses, as well as other vehicles, such as vans and station wagons, may be classified as school buses. Vehicles that are designed and built as school buses, but are operated by the military or other federal, state, or local agencies; churches; or colleges or universities are not classified as school buses.[4]

Vehicles that are designed and built as school buses and that have a GVWR greater than 10,000 lb are defined in this report as Type I buses.[5,6]

A school bus accident (or a school bus-related accident) is any traffic accident in which a school bus (as previously defined) is involved either directly or indirectly. If, for example, a school bus and a passenger car collide, the collision is a school bus accident. The school bus is directly involved. If a child is crossing the street to board a school bus and is struck by a passenger car, this is also a school bus accident, even though the school bus sustained no physical damage. The school bus was indirectly involved.[7]

If a child is struck by a "nonschool bus" (e.g., a passenger car or truck) while walking to or from a school bus stop—or while standing at a bus stop with no school bus present—this type of accident is not a school bus accident. If a school bus is involved in an accident even when no passengers are on board, for purposes of this study this accident is classified as a school bus accident.

Procedure

To determine the safety measures that are most effective in protecting the safety of school children boarding, leaving, and riding in school buses, as requested by Congress, the study followed a three-step procedure:

Step 1: *Definition of the problem.* The scope and etiology of the problem were first defined. How many children are transported by school buses each year? In how many buses? How many of these children are killed and injured as school bus passengers? How many are killed and injured in loading zones? Of those killed and injured in loading zones, how many are struck by their own school buses and how many are struck by other vehicles? What are the causes of these deaths and injuries—both in loading zones and on board school buses?

To answer these questions, a thorough search of the literature was undertaken. Information was solicited from NHTSA, state governors' highway safety representatives, trade associations, and school bus manufacturers and carefully reviewed. School bus accident data from more than 25 states were reviewed and summarized. Fatal school bus accident data in NHTSA's Fatal

Accident Reporting System (FARS) were analyzed for a 5-year period (1982–1986).

The scope of school bus operations in the United States, and the fatalities and injuries that result from those operations, is discussed in Chapters 2 and 3.

Step 2: *Review of potential safety measures.* A list of safety measures was developed that could potentially reduce the frequency of school bus accidents, or the number of deaths and injuries that result from school bus accidents. For each safety measure listed, an attempt was made to estimate (a) the degree to which the measure would reduce the likelihood of deaths and injuries to children transported by school buses and (b) the cost of the measure.

The literature on the effectiveness of school bus safety measures consists of school bus crash tests, sled tests of school bus seats and restraint systems, clinical estimates of the effectiveness of individual safety measures (based on police reports and in-depth accident investigations), and real-world evaluations of specific school bus safety measures.

Safety measures intended to protect children riding in school buses are reviewed in Chapter 4. Safety measures intended to prevent children from being struck while boarding or leaving school buses are reviewed in Chapter 5.

Step 3: *Analysis of the data.* Finally, after the costs and effectiveness of different measures to reduce the number of deaths and injuries were estimated, analyses were undertaken to determine which measures were most cost effective with respect to safety, that is, which measures saved the most lives and reduced the most injuries for each dollar invested.

The results of the comparative analyses conducted in this study are discussed in Chapter 6. The conclusions reached on the basis of these analyses, and the recommendations offered by the committee, are presented in Chapter 7.

Notes

1. The safety record of school buses reflects, in part, the larger size and higher center of gravity of school buses as well as safer operating conditions (e.g., more travel on weekdays during daylight hours) when compared with passenger cars.
2. Letter from Theodore C. Doege, Special Advisor-Science, American Medical Association, Chicago, Ill., to the Transportation Research Board (TRB), October 7, 1987.
3. Letter from Collin C. Rorrie, Executive Director, American College of Emergency Physicians, Dallas, Tex., to TRB, October 23, 1987.
4. This definition of school bus is consistent with the definition in NHTSA's *Fatal Accident Reporting System 1986:* "School bus—a specific type of vehicle which, independent of ownership or design, is used to transport children to and from school, or to and from school activities."

5. This definition of a Type I bus differs from the definition in HSPS 17, which states that Type I buses are vehicles capable of carrying more than 16 people. Because most school buses that are capable of carrying more than 16 people also have a GVWR greater than 10,000 lb, the definitions in HSPS 17 and in this report generally refer to the same vehicles.
6. Type I buses as defined in this report are equivalent to Type B, C, and D buses as defined by the School Bus Manufacturers Institute (SBMI 1985, 1).
7. This definition of "school bus-related accident" is consistent with the definition in NHTSA's *Fatal Accident Reporting System 1986*. "School bus-related accident—any accident in which a vehicle, regardless of body design, used as a school bus is directly or indirectly involved, such as an accident involving school children alighting from a vehicle."

References

ABBREVIATIONS

AAP	American Academy of Pediatrics
NHTSA	National Highway Traffic Safety Administration
NSBSC	National School Bus Standards Conference
NSC	National Safety Council
NTSB	National Transportation Safety Board
PAS	Physicians for Automotive Safety
SAM	Society for Adolescent Medicine
SBMI	School Bus Manufacturers Institute

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2 School Bus Transportation in the United States

THE HISTORY OF PUPIL transportation in the United States, the evolution of the modern school bus from a horse-drawn wagon, the size of the nation's school bus fleet, and the development of minimum safety standards for the manufacture of school buses are reviewed in this chapter.

Pupil Transportation

In 1869 the Commonwealth of Massachusetts passed the first legislation in the United States allowing the use of public funds for transporting school children (Noble 1940, 2). By 1919, with the passage of legislation in Wyoming and Delaware, all 48 states had enacted laws comparable to the Massachusetts statute. The primary reasons that states passed such legislation appear to be (a) state-mandated, compulsory school attendance and (b) the consolidation of public schools (Featherston and Culp 1965, 2-3).

In colonial America, schools were the province of the church rather than the state. Although some states (e.g., Massachusetts in 1642) did require the operation of public schools by local townships, church-supported educational facilities predominated (Featherston and Culp 1965, 1).

During the first half of the 19th century, the public school movement in the United States gained momentum as localities increasingly began to build and operate schools at public expense. By the second half of the century, the public school movement had advanced to the point that the welfare of the state was considered to be dependent on the education of its people. State governments became more actively involved in public education, and school attendance became compulsory. With state and local government involvement in public education, and with the concept of compulsory school attendance well established, the consolidation of public schools to reduce public expenditures and to enhance the quality of education followed.

The transporting of school children at public expense to consolidated schools located at greater distances from their homes was a natural consequence of the changing concept of public education. Without public funds for transportation, consolidated schools would have been unreachable by many students, particularly those living in rural areas. For these students, school attendance would have been impossible, even though compulsory (Featherston and Culp 1965, 2).

In the 20th century states began to provide financial support for public education, and with that support the rate of public school consolidation increased as did the number of children transported to and from schools at public expense—both in absolute numbers and as a percentage of public school enrollment (Figure 2-1).

Two new developments in the 20th century further encouraged the consolidation of public schools and the transporting of school children at public expense: (a) hard surfaced, all-weather roads and (b) the motor vehicle industry. With these developments, schools could be consolidated over larger geographic areas. Commuting distances that would have been prohibitive in the 19th century were now feasible. In 1910 there were almost 0.25 million mi of all-weather, surfaced roads in the United States (Table 2-1). By World War II this number had grown to more than 1.5 million. Also, there were approximately 0.5 million motor vehicles registered in the United States in 1910. By 1940 motor vehicle registrations had increased to more than 32 million.

In the last 50 years, with the expansion of the nation's system of streets and highways and the continuing development of the motor vehicle industry, the number of vehicles used for transporting children to and from school has increased almost sixfold (Table 2-2). The 58,000 vehicles that were used to transport school children at public expense in 1929–1930 increased to nearly 340,000 in 1985–1986.

Each year these vehicles travel more than 3 billion mi; 80 to 85 percent of them are large, "Type I" school buses with gross vehicle weight ratings (GVWR) greater than 10,000 lb that can carry more than 16 passengers. The remaining 15 to 20 percent are smaller, lighter buses that typically carry 16 or fewer passengers. Seventy-five percent of these school buses are operated by local school districts; the remaining 25 percent are operated by private school bus contractors (*School Bus Fleet* 1988, 33).

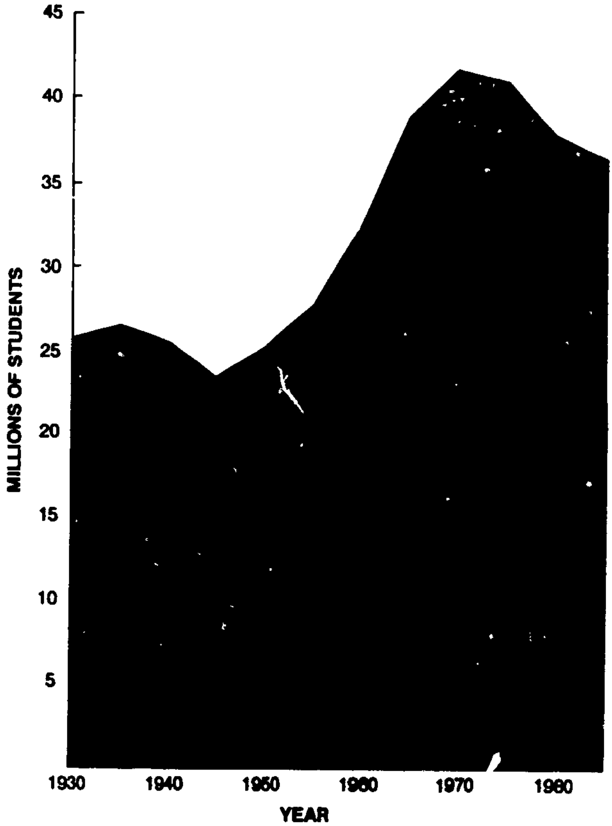

FIGURE 2-1 Students transported at public expense in the United States: 1930–1985 (OERI 1987).

In the fall of 1985 there were 39,508,625 students enrolled in public elementary and secondary schools in the United States (OERI 1987b, 3). During the 1985–1986 school year, some 21,945,021 of these students were transported by bus at a cost to the public of $6.29 billion; that is, $287 per student (*School Bus Fleet* 1988, 33). Clearly, school bus transportation is an integral part of public school education in the United States. Indeed, almost 4 percent of public expenditures on elementary and secondary education in the United States in 1985 was devoted to pupil transportation (OERI 1988, 29).

School Bus Fleet Size

As noted in the preceding section, about 340,000 school buses traveled 3.3 billion mi in 1985–1986 to transport 22 million children to and from school at

TABLE 2-1 HISTORICAL DEVELOPMENT OF SURFACED STREETS AND HIGHWAYS AND MOTOR VEHICLE REGISTRATIONS IN THE UNITED STATES (1900–1985)

Year	Surfaced Streets and Roads[a] (thousands of miles)	Motor Vehicle Registrations[b] (thousands)
1900	NA	8
1905	204	79
1910	245	469
1915	314	2,491
1920	447	9,239
1925	526	20,069
1930	854	26,750
1935	1,255	26,546
1940	1,557	32,453
1945	1,721	31,035
1950	1,939	49,162
1955	2,273	62,689
1960	2,557	73,858
1965	2,776	90,358
1970	2,948	108,418
1975	3,101	132,949
1980	2,044[c]	155,796
1985	2,109[c]	171,654

[a](FHWA 1986 185–187).
[b](FHWA 1[illegible], 26).
[c]Since 1980 "surfaced streets and roads" have not included streets and roads surfaced with soil, gravel, or stone.

public expense. Although these figures account for the bulk of elementary and secondary school transportation in the United States, they exclude most private schools.

Unfortunately, little information is available on the size and scope of private school bus transportation in the United States. The National Transportation Safety Board, for example, recently noted that ". . . there is a lack of information on exposure data and accident statistics involving the transportation of students to private school . . ." and urged more research in this area (NTSB 1983, 17).

In the absence of reliable information about private school transportation, statistics for public schools were increased on the basis of enrollment to obtain rough estimates of the number of public and private school students transported by school buses and the total number of buses used. For school year 1985–1986, approximately 25 million public and private school students were

TABLE 2-2 VEHICLES USED FOR TRANSPORTING STUDENTS AT PUBLIC EXPENSE

School Year	Students Transported at Public Expense[a]	Vehicles Used
1929–1930	1,902,826	58,016
1933–1934	2,794,724	77,042
1937–1938	3,769,242	92,152
1941–1942	4,503,081	92,516
1945–1946	5,056,966	89,299
1949–1950	6,947,384	115,202
1953–1954	8,411,719	147,425
1957–1958	10,861,689	170,689
1961–1962	13,222,667	191,160[b]
1965–1966	15,536,567	NA
1969–1970	18,752,735	239,973
1973–1974	21,169,633	271,552
1977–1978	21,923,780	315,489
1981–1982	22,836,272	335,160
1985–1986	21,945,021	338,854

NOTE: NA indicates not available.
[a](OERI 1987a, 47).
[b](Featherston and Culp 1965, 3).
SOURCE: *School Bus Fleet*, Dec.–Jan. 1988.

transported by a total fleet of 390,000 school buses. Similarly the total number of vehicle miles traveled was increased to 3.8 billion mi to include school buses used for transporting students to private schools.[1]

Development of the School Bus

> The scenes are still vividly etched into the writer's mind of the mules and horses drawing top heavy school wagons with wheels deeply mired, struggling to reach the crest of a sticky red clay hill while the older children trudged along side to lighten the load. The intervening years have not drowned out the sound of the teamster's shouts nor the crack of his bull-whip popping over the heads of the unwary animals (Irwin 1958, 13).

The standard means of transporting children to and from schools in the 19th century was the school wagon, a modified farm wagon pressed into service during the school year to enable children, particularly children from rural areas, to attend consolidated schools. Over the decades the school wagon underwent a series of enhancements designed to improve pupil comfort and safety; for example, canvas tarpaulins drawn over frames of wooden stays were provided to afford some protection from the elements; stoves were added for warmth during cold weather. By World War I motorized trucks were beginning to replace farm wagons as the base structure on which to build school vehicles. Soon, wooden bodies began to replace canvas tarpaulins. By the late 1920s, steel bodies had begun to replace wooden bodies, and the basic concept of the school bus as it exists today—a steel-paneled body attached to a truck chassis—had come into being [Farmer (forthcoming), Part I].

1939 National School Bus Standards Conference

During the 1930s, as school bus transportation gained popularity, a number of states passed legislation giving their departments of education (or other state agencies) the responsibility of setting minimum standards for the construction and equipping of school buses operating within their jurisdictions. By 1939 only 15 states had not passed such legislation [Farmer (forthcoming), Part III].

Early attempts by states to standardize the construction and equipping of school buses resulted in a hodgepodge of specifications (Noble 1940, 280):

> One of the most evident facts concerning standards for school bus construction is the lack of agreement among the several states. The conflicting standards that exist among the states, and in some instances within a single state, have not only been confusing but have also made the cost of school buses unnecessarily high without always increasing pupil safety.

In order to make the standards that were being adopted by the states more uniform, the National Council of Chief State School Officers asked Frank W. Cyr of Columbia University to convene a conference of state and industry representatives and to draft a model set of standards. The purposes of the conference were "(1) to set up uniform minimum standards for safe school buses, and (2) to eliminate conflicts in existing standards which hamper efficient production" [Farmer (forthcoming), Part III].

The first National School Bus Standards Conference was held in New York City in April 1939. Representatives from each of the 48 states were present, as well as representatives from industry (e.g., Bendix Corp., Superior Body Co., General Motors, E.I. duPont de Nemours and Co., U.S. Rubber Co., Ford Motor Co., Chrysler Corp., International Harvester Co., Blue Bird Body Co., Wayne Works, and others) [Farmer (forthcoming), Part III].

The standards, developed as a result of the conference and intended primarily for vehicles designed to carry 20 or more passengers, were divided into two parts: chassis standards and body standards. The 17 recommended chassis standards covered items such as axles, batteries, brakes, bumpers, frames, gasoline tanks, tires, and weight distribution. The 27 recommended body standards addressed aisle widths, ceiling heights, door specifications, lights, mirrors, seat spacings, and so forth (Noble 1940, 288–312).

The standards adopted at the 1939 conference did not carry the weight of law and were not binding on the states. Administrative or legislative actions within the states were necessary to transform these recommendations into requirements (Noble 1940, 287).

Since 1939, nine National School Bus Standards Conferences have been held to enhance and extend the original recommendations.[2] In addition to setting minimum standards for school bus chassis and bodies, the latest recommendations published in 1985 also provide minimum specifications for special education school buses, guidelines for the operation of school buses, and standards for school bus accident report forms (NSBSC 1985).

Federal Motor Vehicle Safety Standards

With passage of the National Traffic and Motor Vehicle Safety Act of 1966 [Public Law 89-563 (September 9, 1966)], the federal government was authorized to issue regulations or standards to improve the safety of motor vehicles manufactured for sale in the United States. Unlike the standards developed at the National School Bus Standards Conferences, standards issued by the National Highway Traffic Safety Administration (NHTSA)—the government agency responsible for developing such standards—are binding on the manufacturers and carry the weight of law.

To date, 33 Federal Motor Vehicle Safety Standards (FMVSS) that apply to school buses have been issued. These standards are divided into two major groups: (a) crash avoidance (FMVSS 100 series) and (b) crashworthiness (FMVSS 200 and 300 series). The standards in the 100 series are intended to prevent accidents. The standards in the 200 series are intended to protect vehicle occupants during a collision, whereas standards in the 300 series are intended to protect occupants during the post-collision phase of an accident. The numbers and titles of federal standards that apply to school buses are given in Table 2-3.

Several of the 33 FMVSS that apply to school buses were issued (or extended) in 1977.[3] These 1977 standards substantially upgraded the safety characteristics—particularly the crashworthiness—of buses manufactured after April 1, 1977, and are, therefore, germane to this study. These standards are discussed in greater detail in Chapter 4.

TABLE 2-3 FEDERAL MOTOR VEHICLE SAFETY STANDARDS THAT APPLY TO SCHOOL BUSES (SBMI 1985, Appendix A)

No.	Standard
Crash avoidance	
101	Control Location, Identification and Illumination
102	Transmission Shift Lever Sequence, Starter Interlocks and Transmission Braking Effect
103	Windshield Defrosting and Defogging Systems
104	Windshield Wiping and Washing Systems
105	Hydraulic Brake Systems
106	Brake Hoses
107	Reflecting Surfaces
108	Lamps, Reflective Devices and Associated Equipment
111	Rearview Mirrors
112	Headlamp Concealment Devices
113	Hood Latches
115	Vehicle Identification Numbers
116	Motor Vehicle Brake Fluids
119	New Pneumatic Tires
120	Tire Selection and Rims
121	Air Brake Systems
124	Accelerator Control System
Crashworthiness	
Crash	
201	Occupant Protection in Interior Impact[a]
203	Impact Protection for the Driver from the Steering Control System[a]
204	Steering Control Rearward Displacement[a]
205	Glazing Materials
207	Seating Systems (Driver's Seat)
208	Occupant Crash Protection (Driver)
209	Seat Belt Assemblies[b]
210	Seat Belt Assembly Anchorages[b]
212	Windshield Mounting[a]
217	Bus Window Retention and Release
219	Windshield Zone Intrusion[a]
220	School Bus Rollover Protection
221	School Bus Body Joint Strength[c]
222	School Bus Passenger Seating and Crash Protection
Post-crash	
301	Fuel System Integrity
302	Flammability of Interior Materials

[a]Applies only to school buses with GVWRs of 10,000 lb or less.
[b]FMVSS 209 and 210 apply to driver's seats on all school buses and to passenger seats on school buses with GVWRs of 10,000 lb or less.
[c]Applies only to school buses with GVWRs greater than 10,000 lb.

Summary

School bus transportation in the United States grew dramatically during this century as public school consolidation increased, hard surfaced, all-weather roads were constructed, and motor vehicles replaced horse-drawn wagons and carriages. By 1930, 58,000 motor vehicles were used to transport school children at public expense. Today, public and private schools and school districts operate about 390,000 school buses, which travel nearly 4 billion mi to transport about 25 million children to and from school and school activities. About 80 to 85 percent of these buses are large, "Type I" school buses with GVWRs greater than 10,000 lb that typically carry more than 16 passengers.

By the late 1920s, the basic concept of the school bus as it exists today had developed—a steel-paneled body attached to a truck chassis. However, it was not until 1939, when the first National School Bus Standards Conference was convened, that a serious attempt was made to develop uniform standards for school bus design and construction. Representatives of the states and school bus manufacturers at this conference and succeeding conferences recommended standards for school buses that individual states could adopt.

The federal government issued no school bus standards until the passage of the National Traffic and Motor Vehicle Safety Act of 1966. Under that act, NHTSA issued 33 standards that apply to school buses. Additions and changes to these standards in 1977 substantially upgraded the safety characteristics, particularly the crashworthiness, of school buses manufactured after April 1, 1977.

Notes

1. In school year 1985–1986, 5,994,144 students attended private elmentary and secondary schools in the United States (OERI 1988, 64). Enrollment in elementary and secondary public schools totaled 39,508,625 in 1985-1986 (OERI 1987b, 3). Because the number of private school students corresponds to 15.1 percent of the number of the public school student population (5,994,144/39,508,625 = 0.151), the total number of buses, miles, and passengers is approximated by 25 million (1.15 × 22), 390,000 (1.15 × 340,000), and 2.8 billion (1.15 × 3.3 billion), respectively.
2. National School Bus Standards Conferences were held in 1945, 1948, 1951, 1954, 1959, 1964, 1970, 1980, and 1985.
3. FMVSS 105, 111, 217, 220, 221, 222, and 301.

References

ABBREVIATIONS

FHWA	Federal Highway Administration
MVMA	Motor Vehicle Manufacturers Association
NSBSC	National School Bus Standards Conference
NTSB	National Transportation Safety Board
OERI	Office of Educational Research and Improvement
SBMI	School Bus Manufacturers Institute

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3 Frequency and Characteristics of School Bus Accidents

SCHOOL BUS ACCIDENT FATALITIES and injuries are described in this chapter. The first section focuses on analysis of fatal school bus accidents from the National Highway Traffic Safety Administration's (NHTSA) Fatal Accident Reporting System (FARS). The discussion is organized into four parts: (a) school bus accident fatalities, (b) school bus and pedestrian accidents and fatalities, (c) fatal accidents involving school bus passengers, and (d) drivers involved in fatal school bus accidents. Estimates of the number of persons (drivers, pedestrians, passengers, and bicyclists) killed annually in school bus accidents are provided.

In the second section school bus accident data from individual states are used to develop nationwide estimates of the number of persons injured in school bus-related accidents each year. School bus accident injuries are described by the victim's role in the accident (driver, pedestrian, passenger, bicyclist) and by injury severity (incapacitating, nonincapacitating, and possible injury). Further detail and discussion of school bus accident data from various states are presented in Appendix A.

Fatal Accidents

Data for a 5-year period were obtained from FARS and analyzed to determine the characteristics and frequency of fatal school bus accidents. FARS is an annual census of fatal traffic accidents that occur throughout the United States. School bus-related accidents that occurred in calendar years 1982 through 1986 were selected because they were the most current available at the time of the analysis. In addition, the committee reviewed police narratives of fatal accidents from three states (California, Michigan, and Pennsylvania). These narratives are presented in Appendix B.

In FARS a school bus-related accident is defined as any traffic accident in which a vehicle functioning as a school bus is involved, either directly or indirectly. For calendar years 1982 through 1986, 642 accidents fit this definition.[1] As seen in the following table, these 642 accidents resulted in 745 fatalities and involved 1,130 vehicles:

	1982	*1983*	*1984*	*1985*	*1986*	*Total*
Accidents	122	133	133	134	120	642
Fatalities	137	160	162	158	128	745
Vehicles	203	235	238	244	210	1,130

Of the 1,130 vehicles involved in these accidents, 484 were designed and built as school buses (excluding van-based buses).[2] Of the remaining 646 vehicles in the data set, 51 were used as school buses.[3] The remaining 595 vehicles (passenger cars, motorcycles, trucks, etc.) were not further subdivided by body type or function. The breakdown by year is as follows:

Vehicles	*1982*	*1983*	*1984*	*1985*	*1986*	*Total*
School buses	90	94	107	106	87	484
Vehicles used as school buses	10	13	11	7	10	51
Other vehicles	103	128	120	131	113	595
	203	235	238	244	210	1,130

School Bus Accident Fatalities

The 745 people who were killed in school bus-related accidents between 1982 and 1986 can be classified by their roles in the accidents [driver, pedestrian, passenger, or bicyclist (pedalcyclist)]. Each fatality can also be associated with a particular vehicle type: vehicles designed and built as school buses (excluding van-based buses), other vehicles externally identifiable as school buses and used as school buses, and all other vehicles (passenger cars, trucks, motorcycles, etc.). For fatally injured drivers and passengers, vehicle type refers to the type of vehicle transporting the fatally injured person; for fatally injured pedestrians and bicyclists, vehicle type refers to the type of vehicle striking the fatally injured person. Figure 3-1 shows that between 1982 and 1986 more than 43 percent of school bus accident fatalities were drivers, another 30 percent were pedestrians, 23 percent were passengers, and approximately 3 percent were bicyclists.

The data on which Figure 3-1 is based are given in detail in Table 3-1. Of the 325 fatally injured drivers, 313 (96 percent) were drivers of other vehicles. The remaining 12 were drivers of school buses or vehicles operated as school buses. Of the 223 fatally injured pedestrians, 156 (70 percent) were struck by a school bus or a vehicle operated as a school bus. Among the 173 vehicle passengers killed in school bus–related accidents, 15 (9 percent) were killed in vehicles operated as school buses, 60 (35 percent) were killed in vehicles designed and built as school buses (excluding van-based buses), and 98 (56 percent) were killed in other vehicles.[4] Three-fourths of the 24 fatally injured bicyclists were struck by a school bus or a vehicle operated as a school bus.

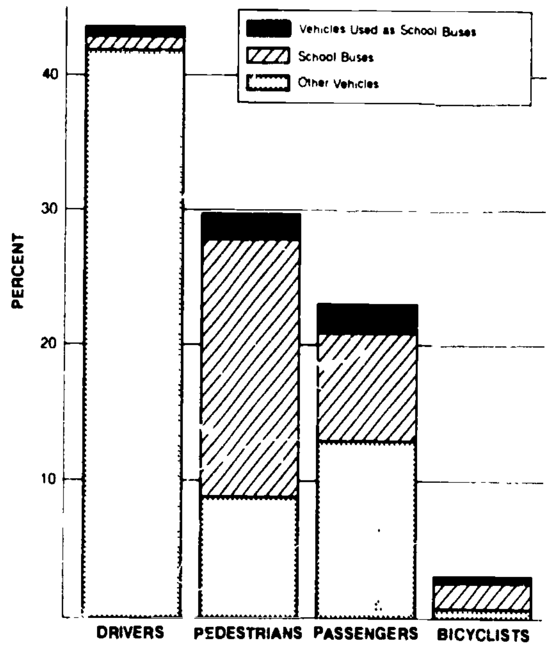

FIGURE 3-1 School bus accident fatalities (FARS 1982–1986). [Note: Drivers and passengers were occupants of the vehicle type indicated. Pedestrians and bicyclists were struck by the vehicle type indicated.]

TABLE 3-1 SCHOOL BUS ACCIDENT FATALITIES, 1982–1986 (FARS 1982–1986)

		Persons Fatally Injured			
Year	Vehicle	Drivers	Pedestrians	Passengers	Bicyclists
1982	School buses[a]	0	31	8	1
	Vehicles used as school buses[b]	1	2	12	1[c]
	Other vehicles	54	15	12	0
1983	School buses	2	31	14	3
	Vehicles used as school buses	0	5	2	1
	Other vehicles	66	12[d]	22	2
1984	School buses	3	26	16	4
	Vehicles used as school buses	2	2	1	0
	Other vehicles	70	11	26	1
1985	School buses	2	26	22	3
	Vehicles used as school buses	0	2	0	0
	Other vehicles	70	13	19	1
1986	School buses	1	28	0	4
	Vehicles used as school buses	1	3	0	1
	Other vehicles	53	16	19	2
Total	School buses	8	142	60	15
	Vehicles used as school buses	4	14	15	3
	Other vehicles	313	67	98	6

[a]"School bus" refers to a vehicle designed and built as a school bus, excluding van-based buses. School buses shown in this table are predominantly Type I buses with GVWRs greater than 10,000 lb.

[b]"Vehicle used as a school bus" refers to a vehicle that is externally identifiable as a school bus, but not originally designed and built as a school bus, for example, station wagons, standard vans, and vans modified to serve as school buses.

[c]Twelve-year-old male nonoccupant struck by a van used as a school bus.

[d]Includes one 3-year-old male pedestrian who was struck by a vehicle of "unknown body type, no special use."

On the basis of these 5 years of FARS data, estimates of the average number of school bus accident fatalities per year were calculated (Table 3-2). As can be seen from Table 3-2, on average, 149 people are killed each year in school bus–related accidents. Sixty-five of these fatalities are drivers. Another 37.4 are pedestrians of student age (under 20 years old). Of the student-age pedestrians killed, an average of 25.8 (69 percent) are killed by school buses or vehicles operating as school buses. Of the 20 student-age passengers killed in school bus–related accidents each year, an average of 9.6 are killed in

TABLE 3-2 ESTIMATED ANNUAL SCHOOL BUS ACCIDENT FATALITIES (FARS 1982–1986)

Persons Fatally Injured	Vehicle Type: School Buses[a]	Vehicles Used as School Buses[b]	Other Vehicles	Total
Drivers	1.6	0.8	62.6	65.0
Pedestrians				
Students[c]	24.0	1.8	11.6	37.4
Adults[d]	4.4	1.0	1.8	7.2
Passengers				
Students	9.6	2.4	8.0	20.0
Adults	2.4	0.6	11.6	14.6
Bicyclists				
Students	1.8	0.4	1.0	3.2
Adults	1.2	0.2	0.2	1.6
	45.0	7.2	96.8	149.0

NOTES: Average values derived from 5 years of fatal accident data. Drivers and passengers were occupants of the vehicle type indicated. Pedestrians and bicyclists were struck by the vehicle type indicated.

[a] "School bus" refers to a vehicle designed and built as a school bus, excluding van-based buses. These vehicles are predominantly Type I buses with GVWRs greater than 10,000 lb.

[b] "Vehicle used as a school bus" refers to a vehicle that is externally identifiable as a school bus, but not originally designed and built as a school bus, for example, station wagons, standard vans, and vans modified to serve as school buses.

[c] Students are defined as persons under 20 years old.

[d] Adults are defined as persons 20 years old or older.

school buses, an average of 2.4 are killed in vehicles operated as school buses, and an average of 8.0 are killed in other vehicles. Finally, an average of 3.2 student-age bicyclists are killed each year in school bus–related accidents.

School Bus and Pedestrian Accidents and Fatalities

Between 1982 and 1986, 187 student-age pedestrians were killed in school bus–related accidents. None of these fatalities occurred on Sunday, and only one occurred on Saturday; the remaining 186 were distributed uniformly from Monday through Friday (Table 3-3). No fatalities were recorded after 7:00 p.m. or before 6:00 a.m. Almost two-thirds of these fatalities were recorded in the afternoon (between 2:00 p.m. and 5:00 p.m.), with more than 40 percent occurring between 3:00 p.m. and 4:00 p.m. (Table 3-4).

TABLE 3-3 STUDENT PEDESTRIANS KILLED IN SCHOOL BUS ACCIDENTS, TOTAL 1982–1986 (FARS 1982–1986)

	Striking Vehicle			
Day	School Buses[a]	Vehicles Used as School Buses[b]	Other Vehicles	Total
Sunday	0	0	0	0
Monday	18	1	16	35
Tuesday	26	2	13	41
Wednesday	17	4	10	31
Thursday	27	2	8	37
Friday	31	0	11	42
Saturday	1	0	0	1
	120	9	58	187

NOTE: Students are defined as persons under 20 years old.

[a]"School bus" refers to a vehicle designed and built as a school bus, excluding van-based buses.

[b]"Vehicle used as a school bus" refers to a vehicle that is externally identifiable as a school bus, but not originally designed and built as a school bus, for example, station wagons, standard vans, and vans modified to serve as school buses.

The data in Table 3-5 indicate that 72 (60 percent) of the 120 student pedestrians struck and killed by school buses were killed on local streets, whereas 41 (34 percent) were killed on U.S. or state routes or county roads. Conversely, of the 58 student pedestrians struck and killed by other vehicles, 50 (86 percent) were killed on U.S. or state routes or county roads, and only 7 (12 percent) were killed on local streets.

Figure 3-2 shows 142 pedestrians fatally injured by school buses as a function of age. Among the 120 fatally injured student pedestrians, 5- and 6-year-olds account for 54 percent of all fatalities. By comparison, 7- and 8-year-olds account for 23 percent of these fatalities. These data suggest that some age-specific safety measures might be appropriate to reduce school bus and pedestrian accidents.

Figure 3-3 shows the number of pedestrians, by age, fatally injured by other vehicles. Unlike the previous figure, young children (5- and 6-year-olds) do not predominate, and the distribution of student fatalities is more even. Five- and 6-year-olds account for 22 percent of student fatalities; 7- and 8-year-olds account for 28 percent.

Fifty-seven "other" vehicles struck and killed the 58 student pedestrians shown in Figure 3-3.[5] As can be seen from Table 3-6, 22 of the other vehicles were sedans, 3 were station wagons, 9 were pickup trucks, 16 were trucks or

TABLE 3-4 STUDENT PEDESTRIANS KILLED IN SCHOOL BUS ACCIDENTS BY TIME OF DAY, TOTAL 1982–1986 (FARS 1982–1986)

	Fatalities	
Time	Frequency	Percent
6:00 a.m.–6:59 a.m.	1	0.5
7:00 a.m.–7:59 a.m.	24	12.8
8:00 a.m.–8:59 a.m.	17	9.1
9:00 a.m.–9:59 a.m.	0	0.0
10:00 a.m.–10:59 a.m.	0	0.0
11:00 a.m.–11:59 a.m.	8	4.3
12:00 noon–12:59 p.m.	6	3.2
1:00 p.m.–1:59 p.m.	3	1.6
2:00 p.m.–2:59 p.m.	21	11.2
3:00 p.m.–3:59 p.m.	79	42.3
4:00 p.m.–4:59 p.m.	22	11.8
5:00 p.m.–5:59 p.m.	4	2.1
6:00 p.m.–6:59 p.m.	2	1.1
	187	100.0

NOTE: Students are defined as persons under 20 years old.

TABLE 3-5 STUDENT PEDESTRIANS KILLED IN SCHOOL BUS ACCIDENTS BY ROAD AND VEHICLE TYPE, TOTAL 1982–1986 (FARS 1982–1986)

	Striking Vehicle			
Road Type	School Buses[a]	Vehicles Used as School Buses[b]	Other Vehicles	Total
Interstate	0	0	0	0
U.S. route	1	0	18	19
State route	17	1	16	34
County road	23	0	16	39
Local street	72	8	7	87
Other or unknown	7	0	1	8
	120	9	58	187

NOTE: Students are defined as persons under 20 years old.

[a]"School bus" refers to a vehicle designed and built as a school bus, excluding van-based buses.

[b]"Vehicle used as a school bus" refers to a vehicle that is externally identifiable as a school bus, but not originally designed and built as a school bus, for example, station wagons, standard vans, and vans modified to serve as school buses

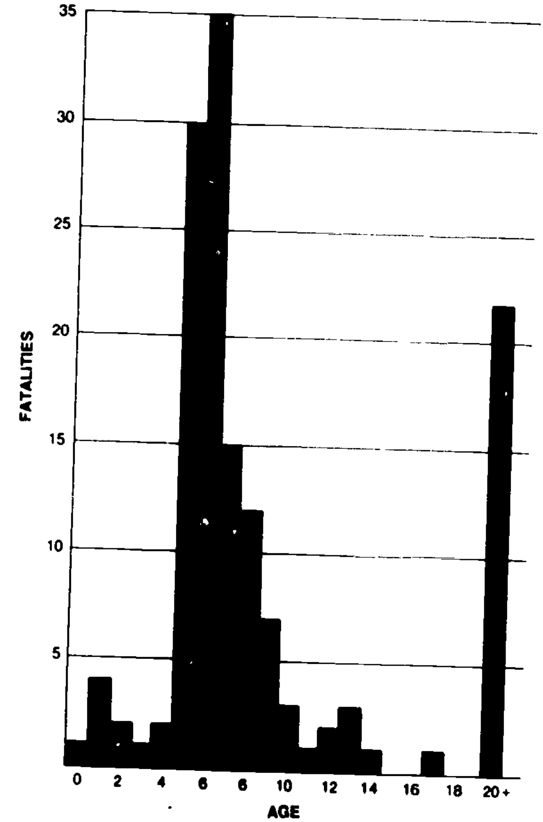

FIGURE 3-2 Age distribution of pedestrians fatally injured by school buses (FARS 1982–1986).

truck-tractors of some type, and 7 were vans or motorcycles. Five of these vehicles had defective brakes, one had defective tires, and one was a hit-and-run vehicle.

Fatal Accidents Involving School Bus Passengers

Between 1982 and 1986, 60 school bus passengers were killed in 26 separate accidents. The ages of the 60 fatally injured passengers are shown in Figure 3-4. Of the 48 student passengers (passengers under 20 years old) killed in these 26 accidents, 28 (58 percent) were teenagers. Of the 26 accidents that

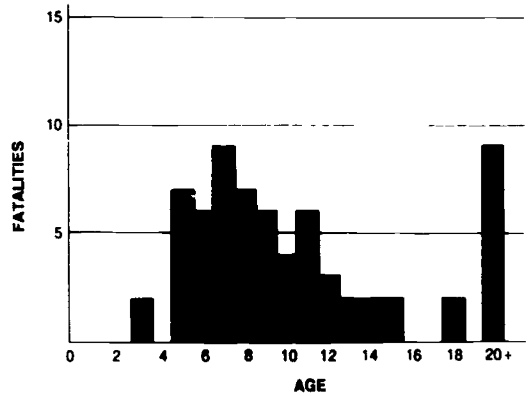

FIGURE 3-3 Age distribution of pedestrians fatally injured by other vehicles (FARS 1982–1986).

resulted in school bus passenger deaths, 2 occurred on weekends (Saturdays). The remainder (Table 3-7) were distributed somewhat unevenly from Monday to Friday, with one-half of the accidents (13 of 26) and approximately one-half of the fatalities (32 of 60) occurring on Thursday and Friday.

Five of the 26 accidents (19 percent) occurred after 6:00 p.m. and before 6:00 a.m. (Table 3-8). More accidents (9) and fatalities (24) occurred between 3:00 p.m. and 4:00 p.m. than at any other hour.

The 26 accidents that resulted in school bus passenger fatalities were distributed fairly evenly among Interstate highways, U.S. and state routes, and county roads (Table 3-9); only 1 of the accidents occurred on a local street.

The "first harmful event" in 15 of the 26 accidents was collision with another motor vehicle. In 6 accidents, collision with a fixed object was the first harmful event, and in 3 others, falling from the bus was the first harmful event. Overturning was not the first harmful event in any of these accidents, but nine buses did overturn after colliding with other motor vehicles or fixed objects (Table 3-10).

The initial point of impact and the principal point of impact on each of the 26 school buses are given in Table 3-11. Initial impact point refers to that point on the bus that produced the first property damage or personal injury. Principal impact point refers to that point on the bus that produces the most property damage or personal injury. Clearly, frontal impacts are the predominant points of impact.

Finally, only 1 of the 26 school buses caught fire after the collision. Eight school bus passengers died in this accident, but none died as a result of the fire (NTSB 1984).

TABLE 3-6 OTHER VEHICLES THAT STRUCK AND KILLED STUDENT PEDESTRIANS, TOTAL 1982–1986 (FARS 1982–1986)

	Road Type					
Body Type	U.S. Route	State Route	County Road	Local Street	Other/ Unknown	Total
Two-door sedan, hardtop, coupe	2	4	5[a]	1	0	12
Four-door sedan, hardtop	4	2	3	1	0	10
Station wagon	0	1	0	2	0	3
Unknown automobile type	0	1	1	0	0	2
Motorcycle	0	0	1	0	0	1
Unknown bus type	0	0	1	0	0	1
Van	0	1	0	0	0	1
Van--commercial cutaway	0	1	0	0	0	1
Pickup	3	2[b]	2	1	1	9
Truck-based utility	1	0	0	0	0	1
Unknown light conventional truck	1	0	0	0	0	1
Single-unit straight truck (GVWR > 26,000 lb)	0	2	0	0	0	2[c]
Truck-tractor	4	1	1	1	0	7
Unknown heavy truck (GVWR > 26,000 lb)	1	0	1	0	0	2[b]
Single-unit straight truck (GVWR unknown)	0	1	1	0	0	2
Unknown truck type	1	0	0	0	0	1
Unknown body type	0	0	0	1[d]	0	1
	17	16	16	7	1	57

NOTE: Students are defined as persons under 20 years old.
[a]One of the vehicles had defective brakes.
[b]One of the vehicles had defective tires.
[c]Both of the vehicles had defective brakes.
[d]Hit-and-run accident.

Drivers Involved in Fatal School Bus Accidents

Between 1982 and 1986, 1,130 vehicles were involved in fatal school bus accidents; information was available on the drivers of 1,124 vehicles. Some 185 of these drivers were school bus drivers[6] involved in single-vehicle accidents; 346 were school bus drivers involved in multivehicle accidents.[7] Another 70 were drivers of other vehicles (automobiles, trucks, etc.) involved in single-vehicle accidents, and 523 were drivers of other vehicles involved in multivehicle accidents.

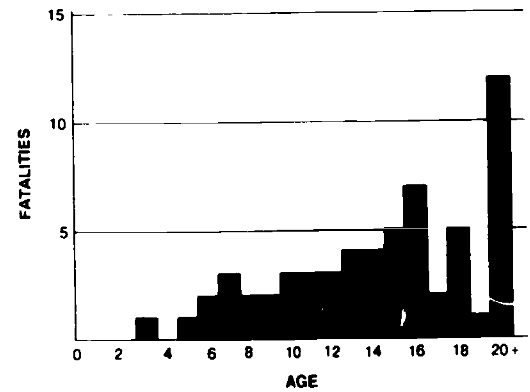

FIGURE 3-4 Passengers fatally injured in Type I school buses (FARS 1982–1986).

TABLE 3-7 ACCIDENTS THAT RESULTED IN SCHOOL BUS PASSENGER FATALITIES BY DAY OF WEEK, TOTAL 1982–1986 (FARS 1982–1986)

Day	Accidents	Fatalities
Sunday	0	0
Monday	5	7
Tuesday	3	6
Wednesday	3	6
Thursday	7	11
Friday	6	21
Saturday	2	9
	26	60

NOTE: "School bus" refers to a vehicle designed and built as a school bus, excluding van-based buses.

The violations with which the 1,124 drivers were charged are given in Table 3-12. As might be expected, drivers involved in single-vehicle accidents appear to be charged with violations more often than drivers in multivehicle accidents. Four (6 percent) of the drivers of other vehicles involved in single-vehicle accidents were charged with driving under the influence of alcohol or drugs, 2 (3 percent) were speeding, 3 (4 percent) were charged with reckless driving, and 9 (13 percent) were charged with some other moving violation.

Histories of the 1,124 drivers involved in fatal school bus accidents are given in Tables 3-13 through 3-16. The data in Table 3-13 indicate that school

TABLE 3-8 ACCIDENTS THAT RESULTED IN SCHOOL BUS PASSENGER FATALITIES BY TIME OF DAY, TOTAL 1982–1986 (FARS 1982–1986)

Time	Accidents	Fatalities
6:00 a.m.–6:59 a.m.	2	3
7:00 a.m.–7:59 a.m.	3	3
8:00 a.m.–8:59 a.m.	3	3
9:00 a.m.–9:59 a.m.	0	0
10:00 a.m.–10:59 a.m.	1	1
11:00 a.m.–11:59 a.m.	1	1
12:00 noon–12:59 p.m.	0	0
1:00 p.m.–1:59 p.m.	0	0
2:00 p.m.–2:59 p.m.	2	3
3:00 p.m.–3:59 p.m.	9	24[a]
4:00 p.m.–4:59 p.m.	0	0
5:00 p.m.–5:59 p.m.	0	0
6:00 p.m.–5:59 a.m.	5	22
	26	60

NOTE: "School bus" refers to a vehicle designed and built as a school bus, excluding van-based buses.

[a]Eight of the 24 fatally injured passengers were killed in one crash.

TABLE 3-9 ACCIDENTS THAT RESULTED IN SCHOOL BUS PASSENGER FATALITIES BY ROAD TYPE, TOTAL 1982–1986 (FARS 1982–1986)

Road Type	Accidents	Fatalities
Interstate	5	9
U.S. route	5	21
State route	8	21
County road	5	6
Local street	1	1
Other	2	2
	26	60

NOTE: "School bus" refers to a vehicle designed and built as a school bus, excluding van-based buses.

TABLE 3-10 ACCIDENTS THAT RESULTED IN SCHOOL BUS PASSENGER FATALITIES BY FIRST HARMFUL EVENT, TOTAL 1982–1986 (FARS 1982–1986)

	School Bus Overturned		
First Harmful Event	Yes	No	Total
Collision with			
Other vehicle in traffic	6 (12)	9 (25)	15 (37)
Fixed object[a]	3 (13)	3 (4)	6 (17)
Railroad train	0	1 (2)	1 (2)
Noncollision			
Passenger fell from bus	0	3 (3)	3 (3)
Other	0	1 (1)	1 (1)
Total	9 (25)	17 (35)	26 (60)

NOTES: "School bus" refers to a vehicle designed and built as a school bus, excluding van-based buses. Numbers in parentheses represent passengers killed.

[a]One culvert, two ditches, one tree, one guardrail, and one embankment.

TABLE 3-11 ACCIDENTS THAT RESULTED IN SCHOOL BUS PASSENGER FATALITIES BY POINT OF IMPACT, TOTAL 1982–1986 (FARS 1982–1986)

Point of Impact	Initial	Principal
Front (11, 12, 1)[a]	14	11
Right side (2, 3, 4)	3	3
Rear (5, 6, 7)	3	2
Left side (8, 9, 10)	2	2
Undercarriage	0	1
Top	0	3
Noncollision	3	3
Unknown	1	1
	26	26

NOTE: "School bus" refers to a vehicle designed and built as a school bus, excluding van-based buses.

[a]Numbers in parentheses refer to clock points: 12 o'clock is the front center of the bus; 6 o'clock is the rear of the bus. Points 11, 12, and 1 generally define points of impact to the front of the bus; 2, 3, and 4 define the right side of the bus, and so forth.

bus drivers involved in fatal single-vehicle accidents were involved in more accidents in the 3 years before the accident occurred than were school bus drivers involved in multivehicle accidents. For multivehicle accidents, drivers of other vehicles were more likely than school bus drivers to have been involved in other accidents during the 3 years before their fatal school bus accident.

Drivers of other vehicles are much more likely than school bus drivers to have had their license suspended or revoked during the previous 3 years (Table 3-14). This is the case for drivers involved in both single- and multivehicle accidents. More than 20 percent of the drivers of other vehicles involved in fatal single-vehicle school bus accidents, and for whom suspension and revocation history are reported, had one or more license suspensions or revocations recorded in the previous 3 years.

Only 1 of the 531 school bus drivers considered in this analysis was known to have been convicted of driving while intoxicated (DWI) during the previous 3 years (Table 3-15). Of the 593 drivers of other vehicles, 24 had been convicted of DWI once in the previous 3 years, and 4 had been convicted twice.

The data in Table 3-16 indicate that approximately 12 percent of 531 school bus drivers in the data set had been convicted of speeding on one or more occasions in the previous 3 years. By comparison, 25 to 35 percent of all

TABLE 3-12 DRIVERS INVOLVED IN FATAL SCHOOL BUS ACCIDENTS, 1982–1986 (FARS 1982–1986)

	Single-Vehicle Accidents (%)		Multivehicle Accidents (%)	
Violation Charged	School Bus Drivers[a] (N = 185)	Drivers of Other Vehicles (N = 70)	School Bus Drivers[a] (N = 346)	Drivers of Other Vehicles (N = 523)
None	77.3	64.3	84.1	80.1
Alcohol or drugs	1.1	5.7	0.0	1.3
Speeding	0.0	2.9	0.3	2.5
Reckless driving	2.7	4.3	1.2	1.1
Suspended license	0.0	0.0	0.3	0.4
Other moving violation	9.2	12.9	7.5	8.2
Nonmoving violation	3.2	4.3	0.6	1.0
Other or unknown	6.5	5.6	6.0	5.4
	100.0	100.0	100.0	100.0

[a]Includes drivers of any vehicles operated as school buses and externally identifiable as school buses.

TABLE 3-13 PREVIOUS ACCIDENTS FOR DRIVERS INVOLVED IN FATAL SCHOOL BUS ACCIDENTS, 1982–1986 (FARS 1982–1986)

	Single-Vehicle Accidents (%)		Multivehicle Accidents (%)	
Previous 3 Years	School Bus Drivers[a] (*N* = 185)	Drivers of Other Vehicles (*N* = 70)	School Bus Drivers[a] (*N* = 346)	Drivers of Other Vehicles (*N* = 523)
None	80.5	78.6	85.3	78.2
1	15.1	14.3	10.7	14.3
2	3.8	2.9	2.6	3.6
3	0.0	0.0	0.6	1.1
4	0.0	0.0	0.6	0.2
Unknown	0.6	4.2	0.2	2.6
	100.0	100.0	100.0	100.0

[a]Includes drivers of any vehicles operated as school buses and externally identifiable as school buses.

TABLE 3-14 RECORDED SUSPENSIONS AND REVOCATIONS FOR DRIVERS INVOLVED IN FATAL SCHOOL BUS ACCIDENTS, 1982–1986 (FARS 1982–1986)

	Single-Vehicle Accidents (%)		Multivehicle Accidents (%)	
Previous 3 Years	School Bus Drivers[a] (*N* = 185)	Drivers of Other Vehicles (*N* = 70)	School Bus Drivers[a] (*N* = 346)	Drivers of Other Vehicles (*N* = 523)
0	96.2	81.4	98.3	88.3
1	2.2	10.0	1.4	6.9
2	0.0	2.9	0.0	2.1
3	0.4	1.4	0.0	0.2
4	0.4	0.0	0.0	0.0
5	0.4	0.0	0.0	0.0
Unknown	0.4	4.3	0.3	2.5
	100.0	100.0	100.0	100.0

[a]Includes drivers of any vehicles operated as school buses and externally identifiable as school buses.

drivers of other vehicles had been convicted of speeding on one or more occasions in the previous 3 years. Of the 70 drivers of other vehicles who were involved in fatal single-vehicle accidents (typically pedestrian accidents), 13 had been convicted of speeding once in the previous 3 years, 7 had been convicted twice, and 1 had been convicted three times.

TABLE 3-15 DWI CONVICTIONS FOR DRIVERS INVOLVED IN FATAL SCHOOL BUS ACCIDENTS, 1982–1986 (FARS 1982–1986)

	Single-Vehicle Accidents (%)		Multivehicle Accidents (%)	
Previous 3 Years	School Bus Drivers[a] (N = 185)	Drivers of Other Vehicles (N = 70)	School Bus Drivers[a] (N = 346)	Drivers of Other Vehicles (N = 523)
0	99.5	88.6	99.4	93.1
1	0.0	4.3	0.3	4.0
2	0.0	2.9	0.0	0.4
Unknown	0.5	4.2	0.3	2.5
	100.0	100.0	100.0	100.0

[a]Includes drivers of any vehicles operated as school buses and externally identifiable as school buses.

In summary, the driving records of school bus drivers involved in fatal school bus accidents are good, and certainly better than the driving records of other drivers involved in fatal school bus accidents (Tables 3-13 through 3-16).

Accidents Resulting in Injuries

The number of persons injured each year in school bus–related accidents and the severities of the injuries they sustain are not well known. There is no national census or representative sample of school bus–related accidents, no systematic count of injuries suffered in these accidents, nor any rigorous assessment of the degree to which passengers are injured. In the absence of such information, only gross estimates of the frequency and severity of injuries resulting from school bus–related accidents are available.

School Bus Accident Injuries

The National Safety Council (NSC) reports that in 1986 there were 37,000 school bus accidents in the United States that resulted in injuries to 11,500 people, 6,900 of them students. However, in 1986, 15 states did not submit school bus accident injury data to the NSC. For these states the council had to estimate school bus accident injuries (NSC 1987). Furthermore, school bus accident and injury data are frequently submitted to NSC by state departments

TABLE 3-16 SPEEDING CONVICTIONS FOR DRIVERS INVOLVED IN FATAL SCHOOL BUS ACCIDENTS 1982–1986 (FARS 1982–1986)

	Single-Vehicle Accidents (%)		Multivehicle Accidents (%)	
Previous 3 Years	School Bus Drivers[a] (N = 185)	Drivers of Other Vehicles (N = 70)	School Bus Drivers[a] (N = 346)	Drivers of Other Vehicles (N = 523)
0	88.1	65.7	87.6	73.6
1	9.7	18.6	10.7	14.3
2	1.1	10.0	0.9	5.4
3	0.0	1.4	0.3	2.1
4	0.0	0.0	0.3	1.0
5	0.0	0.0	0.0	0.4
6	0.5	0.0	0.0	0.6
7	0.0	0.0	0.0	0.2
Unknown	0.6	4.3	0.2	2.4
	100.0	100.0	100.0	100.0

[a]Includes drivers of any vehicles operated as school buses and externally identifiable as school buses.

of education whose school bus accident statistics often fall well below figures cited by state police or departments of motor vehicles (e.g., see Figure A-1, Appendix A).

Although the data reported to NSC by departments of education may be accurate (given the definitions under which those data are collected) and useful to the departments, they probably understate the number of injuries that result from school bus accidents each year. Consequently, the study committee developed its own estimate of the number of persons injured annually in school bus–related accidents on the basis of data from 14 states (Table 3-17). For each of these states, data were available for calendar year 1986 (or school year 1985–1986) to indicate the number of persons injured in school bus accidents (I), number of miles traveled by school buses (M), number of buses operated (B), and number of pupils transported on a daily basis (T). For the 14 states in aggregate, 7,145 injuries were recorded (i.e., 4.713 persons injured per million miles of school bus service, 4.976 persons injured per hundred school buses, and 7.230 persons injured per ten thousand pupils transported).

When these three injury rates are applied to national estimates of miles of school bus service, number of school buses operated, and number of pupils transported, the following national estimates of school bus accident injuries are generated:[8]

Injury Rates Based on Data from 14 States	*National Estimates of Exposure*	*National Estimates of Persons Injured*
$4{,}713 \times 10^{-6}$ persons injured per mile of school bus service	3.8×10^{9} miles of school bus service	17,909
4.976×10^{-2} persons injured per school bus	3.9×10^{5} school buses	19,406
7.230×10^{-4} persons injured per pupil transported	2.5×10^{7} pupils transported	18,075

The three estimates are consistent, and the committee used the higher figure rounded to 19,000 as its estimate of the number of persons injured in school bus–related accidents in the United States each year. The higher figure was selected in order to be conservative, that is, to reduce the possibility of underestimating the number of school bus accident injuries.

Of the 19,000 persons injured in school bus–related accidents each year, it was further estimated that 10 percent (1,900) are school bus drivers; 50 percent (9,500) are school bus passengers; 5 percent (950) are pedestrians; and 35 percent (6,650) are other motorists, bicyclists, and so forth. These

TABLE 3-17 SCHOOL BUS ACCIDENT INJURY AND EXPOSURE STATISTICS FOR SELECTED STATES FOR CALENDAR YEAR 1986 (or school year 1985–1986)

State	Persons Injured (I)	Miles of Service (M)	Buses (B)	Pupils Transported (T)
Delaware	128	16,021,598	1,264	81,557
Florida	604	138,455,812	8,652	748,920
Kansas	53	6,580,149	5,144	163,812
Kentucky	296	72,191,000	6,656	416,563
Louisiana	90	65,108,194	7,429	583,237
Maryland	336	76,275,363	4,975	441,089
Michigan	840[a]	114,245,331	14,090	560,000
Minnesota	265	116,473,000	9,959	859,120
New York	1,739	200,892,872	15,090	2,004,920
North Carolina	1,028	115,665,123	13,002	697,733
Oregon	25	43,170,484	4,556	233,828
Pennsylvania	481	243,252,787	19,345	1,345,002
Texas	1,022	224,749,001	24,107	1,020,907
Virginia	238	83,036,928	9,312	725,856
	7,145	1,516,117,642	143,581	9,882,544

NOTE: Injury data were provided by 14 states. Exposure data (M, B, and T) are from *School Bus Fleet*, Dec.–Jan. 1988, p. 33.

[a]1984–1985 data

TABLE 3-18 NUMBER OF PERSONS INJURED IN SCHOOL BUS-RELATED ACCIDENTS BY ROLE IN ACCIDENT FOR SELECTED STATES

	Role in Accident (%)				Total	
State	School Bus Drivers	School Bus Passengers	Pedestrians	All Others	Percent	Frequency
Delaware[a]	6.6	68.7	NA	24.7[b]	100.0	457
Maryland[c]	11.2	60.1	4.8	23.9	100.0	1,850
Texas[d]	6.5	42.7	4.9	45.9	100.0	7,662
Oregon[c]	8.6	36.3	10.9	44.2	100.0	256
Kentucky[e]	7.6	68.2	2.9	21.3	100.0	1,024
North Carolina[c]	6.5	62.0	0.9	30.6	100.0	6,427
New York[d]	10.1	52.0	3.0	34.9	100.0	13,026
Louisiana[c]	5.9	NA	77.2[f]	16.9	100.0	1,380
Illinois[g]	10.3	40.0	3.3	46.4	100.0	5,195
Michigan[h]	8.1	20.7	6.1	65.1	100.0	3,293
National estimate[i]	10.0	50.0	5.0	35.0	100.0	

NOTE: NA indicates data not available.

[a] 1981–1982 through 1985–1986.

[b] Includes pedestrians or "other."

[c] 1980–1981 through 1986–1987.

[d] 1980 through 1986.

[e] 1983–1984 through 1986–1987.

[f] Includes school bus passengers or pedestrians.

[g] 1981 through 1986.

[h] 1980–1981 through 1984–1985.

[i] These rounded values were selected as being representative of the above state data but are not averages of the individual state statistics.

estimates are based on data provided by 10 states (Table 3-18). The variability of the data given in Table 3-18 makes difficult the task of apportioning school bus accident casualties into different categories. The estimates provided represent the committee's best judgment based on few available data.

Of the estimated 9,500 injured school bus passengers, 5 percent (475) sustained incapacitating (A-level) injuries, 25 percent (2,375) sustained nonincapacitating (B-level) injuries, and 70 percent (6,650) sustained possible (C-level) injuries. (Injury severity categories are discussed in the next section.) These estimates are based on other highly variable data provided by six states (Table 3-19). Although some of the 9,500 injured school bus passengers may have been nonstudents (coaches, monitors, teachers, etc.), for this study all 9,500 were assumed to be students.

Of the 950 pedestrians injured, 85 percent (808) are assumed to be students (Table 3-20). This estimate is based on data from four states—Illinois,

TABLE 3-19 SCHOOL BUS PASSENGERS INJURED IN SCHOOL BUS ACCIDENTS BY SELECTED STATES

	State (%)						
Injury Severity	California[a,b] (N = 2,942)	Kansas[c] (N = 165)	Maryland[d] (N = 907)	Michigan[e] (N = 683)	New York[f] (N = 5,624)	North Carolina[a] (N = 3,985)	National Estimate (%)
Incapacitating	1.0	14.5	12.3	5.4	3.3	3.2	5.0
Nonincapacitating	24.9	NA	NA	24.3	26.5	20.5	25.0
Possible	74.1	85.5[g]	87.7[h]	70.3	70.2	76.3	70.0
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

NOTE: NA indicates data not available.

[a]Includes pupil passengers only.
[b]1980–1981 through 1986–1987.
[c]1982–1986.
[d]1981–1982 through 1984–1987.
[e]1980–1981 through 1984–1985.
[f]1980–1986.
[g]Sustained nonincapacitating or possible injuries.
[h]Sustained nonincapacitating or possible injuries.

Michigan, New York, and Texas. Students are defined as persons under 20 years old. Undoubtedly, some of these pedestrians are preschoolers or teenagers no longer in school, but all 808 are assumed to be students.

Approximately 35 percent (283) of all students injured as pedestrians in school bus accidents are injured when they are struck by school buses. The remaining 65 percent (525) are injured when struck by other vehicles. These estimates are based on data supplied by three states—Michigan, North Carolina, and Texas (Table 3-21).

Of those students injured as pedestrians in school bus–related accidents, 20 percent sustained incapacitating injuries, 30 percent sustained nonincapacitating injuries, and 50 percent sustained possible injuries. These estimates are based on data from California, New York, and North Carolina (Table 3-22). The distributions of injury severities sustained by students struck by school buses and by other vehicles are assumed to be equal.

Figure 3-5 shows the 19,000 school bus accident injuries and 149 fatalities that occur each year in the United States. This figure also shows the severity of the injuries sustained by the 10,308 students and how they were injured in these accidents.

Injury Severity Ratings

Injury severity ratings derived from police accident reports are, necessarily, imprecise measures of the trauma sustained by individuals involved in motor

TABLE 3-20 PEDESTRIANS INJURED IN SCHOOL BUS–RELATED ACCIDENTS BY AGE FOR SELECTED STATES

Pedestrians Injured	State (%) Illinois[a] (N = 162)	Michigan[b] (N = 209)	New York[c,d] (N = 373)	Texas[c] (N = 350)	National Estimate (%)
Students[e]	59.3	84.7	57.1	91.7	85.0
Adults[f]	40.7	15.3	42.9	8.3	15.0
	100.0	100.0	100.0	100.0	100.0

[a]1981–1986.
[b]1980–1981 through 1984–1985.
[c]1980–1986.
[d]Includes fatally injured pedestrians.
[e]Students are defined as persons under 20 years old.
[f]Adults are defined as persons 20 years old or older

TABLE 3-21 PEDESTRIANS INJURED IN SCHOOL BUS–RELATED ACCIDENTS BY VEHICLE TYPE FOR SELECTED STATES

Pedestrians Struck by	State (%) Michigan[a] (N = 201)	North Carolina[b] (N = 57)	Texas[c] (N = 373)	National Estimate (%)
School buses	36.3	78.9	28.2	35.0
Other vehicles	63.7	21.1	71.8	65.0
	100.0	100.0	100.0	100.0

[a]Data supplied by the Traffic Services Division of the Michigan State Police for school years 1980–1981 through 1984–1985.
[b]Data supplied by the Traffic Records Section of the North Carolina Division of Motor Vehicles, Report TR-18 for school years 1980–1981 through 1986–1987.
[c]Data supplied by the Statistical Services Section of the Texas Department of Public Safety for calendar years 1980 through 1986.

TABLE 3-22 PEDESTRIANS INJURED IN SCHOOL BUS–RELATED ACCIDENTS BY INJURY SEVERITY FOR SELECTED STATES

Injury Severity	State (%) California[a,b] (N = 54)	New York[b] (N = 424)	North Carolina[c] (N = 57)	National Estimate (%)
Incapacitating	5.6	13.7	35.1	20.0
Nonincapacitating	68.5	32.3	28.1	30.0
Possible	25.9	54.0	36.9	50.0
	100.0	100.0	100.0	100.0

[a]Includes student pedestrians only.
[b]1980–1986.
[c]1980–1981 through 1986–1987.

vehicle accidents. The American National Standards Institute (ANSI) injury scale (D16.1) is used by most states. This injury severity rating scale is divided into three levels of nonfatal injury as follows (NSC 1984, 10–11):

Level A: Incapacitating injury. Any injury that prevents the injured person from walking, driving, or normally continuing the activities he was capable of performing before the injury occurred.

Inclusions: Severe lacerations, broken or distorted limbs, skull or chest injuries, abdominal injuries, unconscious at or when taken from the accident scene; unable to leave accident scene without assistance; and others.

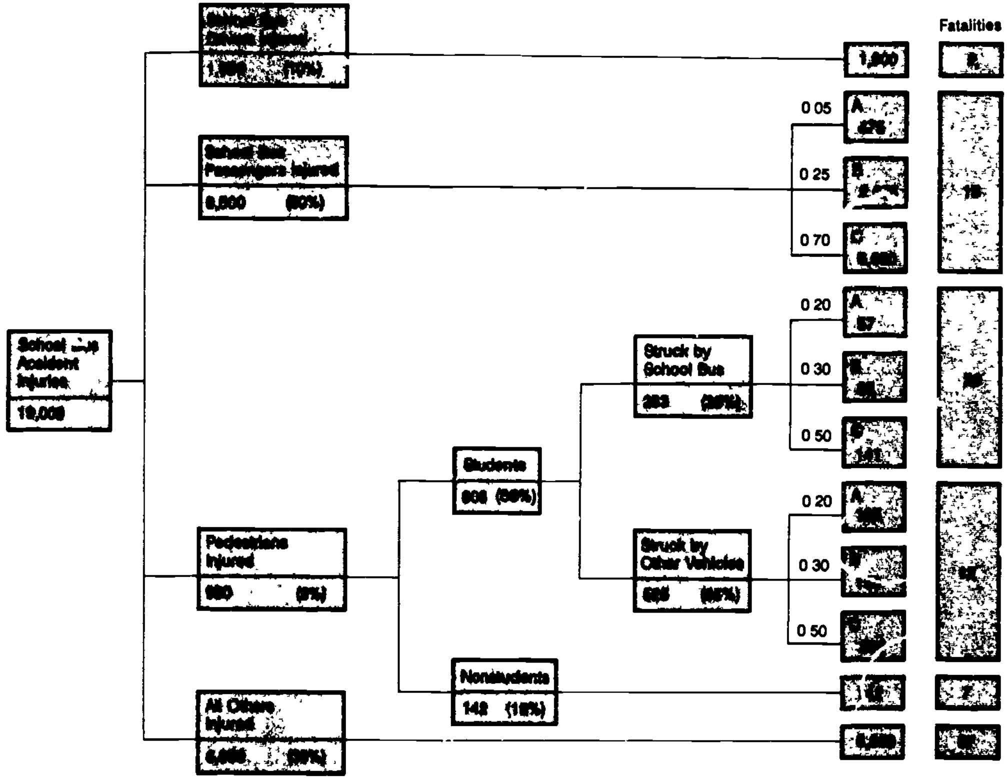

FIGURE 3-5 Annual fatalities and injuries in school bus accidents.

Exclusion: Momentary unconsciousness; and others.

Level B: Nonincapacitating evident injury. Any injury, other than a fatal injury or an incapacitating injury, that is evident to observers at the scene of the accident where the injury occurred.

Inclusions: Lump on head, abrasions, bruises, minor lacerations; and others.

Exclusion: Limping (the injury cannot be seen); and others.

Level C: Possible injury. Any injury reported or claimed that is not a fatal injury, incapacitating injury, or nonincapacitating evident injury.

Inclusions: Momentary unconsciousness. Claim of injuries not evident. Limping, complaint of pain, nausea, hysteria; and others.

Three points should be noted about the use of the ANSI D16.1 scale before the severity of injuries sustained by persons involved in school bus accidents is considered. First, not all states use the ANSI D16.1 scale to report injury severity. California, for example, codes accident severity into three categories defined as A, severe; B, moderate; and C, complaint of pain. The correlation between California's scale and the ANSI D16.1 scale is unknown. Second, because a state claims to use the ANSI D16.1 scale in reporting accident injuries is no guarantee that individual police officers apply this scale accurately when reporting injury severity. Furthermore, in some states injury severity information may be provided by drivers involved in the accidents, as well as by police officers (e.g., New York, Texas). Third, to divide traumatic injury into just three categories guarantees that injuries of vastly different severity must, of necessity, be grouped under the same severity level. For example, under the ANSI D16.1 scale, injuries ranging from broken arms to quadriplegia are all classified as incapacitating injuries.

To better understand the severity of injuries sustained by persons involved in school bus accidents, consider the data in Tables 3-23 and 3-24 provided by the New York Department of Motor Vehicles. Table 3-23 gives police-reported injuries sustained by school bus passengers; Table 3-24 gives police-reported injuries sustained by pedestrians arriving at or leaving a stopped school bus. More than 40 percent of the 170 school bus passengers who sustained A-level (incapacitating) injuries had head or facial injuries. Twenty-five percent sustained concussions and another 25 percent suffered fractured or dislocated bones. Five percent were unconscious. Among the 2,619 school bus passengers who sustained C-level (possible injuries), approximately one-third received head or facial injuries.

Of the 56 pedestrians sustaining A-level (incapacitating) injuries, 30 percent sustained head injuries and 36 percent sustained injuries to the lower extremities (Table 3-24). Nine percent suffered injuries over their entire body. More than 60 percent suffered fractured or dislocated bones, and another 5

TABLE 3-23 POLICE-REPORTED INJURIES SUSTAINED BY PASSENGERS IN SCHOOL BUS ACCIDENTS IN NEW YORK (1980–1986)

	Injury Severity (%)		
	A (*N* = 170)	B (*N* = 971)	C (*N* = 2,619)
Location of Most Severe Physical Complaint			
Head	33.4	31.7	27.9
Face	10.0	32.7	6.1
Eye	14.1	1.4	0.0
Neck	5.9	1.1	12.6
Chest	2.4	2.0	3.2
Back	1.8	1.1	9.3
Shoulder/upper arm	4.1	3.1	5.9
Elbow/lower arm/hand	7.1	8.7	4.8
Abdomen/pelvis	4.7	0.5	2.7
Hip/upper leg	5.9	2.9	2.7
Knee/lower leg/foot	6.5	12.8	10.0
Entire body	1.8	0.4	5.9
Unspecified	2.3	1.6	8.9
	100.0	100.0	100.0
Most Severe Physical Complaint			
Amputation	0.6	0.0	0.0
Concussion	27.0	0.0	0.0
Internal	9.4	0.0	0.0
Minor bleeding	6.5	30.9	0.0
Severe bleeding	14.7	0.0	0.0
Minor burn	0.6	0.6	0.0
Moderate burn	0.0	0.0	0.0
Severe burn	0.0	0.0	0.0
Fracture/dislocation	24.7	0.0	0.0
Contusion/bruise	0.6	53.0	0.0
Abrasion	0.6	15.5	0.0
Complaint of pain	12.9	0.0	77.7
None visible	2.4	0.0	16.9
Unspecified	0.0	0.0	5.4
	100.0	100.0	100.0
Victims' Physical and Emotional Status			
Unconscious	4.7	0.0	0.0
Semiconscious	11.8	0.0	0.0
Incoherent	2.9	0.0	0.0
Shock	3.5	1.1	1.3
Conscious	77.1	98.9	98.7
	100.0	100.0	100.0

TABLE 3-24 POLICE-REPORTED INJURIES SUSTAINED BY PEDESTRIANS GOING TO AND FROM STOPPED SCHOOL BUSES IN NEW YORK (1980–1986)

	Injury Severity (%)		
	A (N = 56)	B (N = 130)	C (N = 192)
Location of Most Severe Physical Complaint			
Head	30.4	26.9	11.5
Face	0.0	9.2	1.6
Eye	1.8	0.0	0.0
Neck	1.8	0.0	1.0
Chest	0.0	1.5	1.0
Back	0.0	2.3	5.7
Shoulder/upper arm	7.1	4.6	5.2
Elbow/lower arm/hand	5.4	10.0	6.8
Abdomen/pelvis	1.8	0.0	4.2
Hip/upper leg	5.4	13.1	18.2
Knee/lower leg/foot	35.6	30.8	37.0
Entire body	8.9	0.8	5.2
Unspecified	1.8	0.8	2.6
	100.0	100.0	100.0
Most Severe Physical Complaint			
Amputation	5.4	0.0	0.0
Concussion	12.5	0.0	0.0
Internal	3.6	0.0	0.0
Minor bleeding	3.6	19.2	0.0
Severe bleeding	10.7	0.0	0.0
Minor burn	0.0	0.0	0.0
Moderate burn	0.0	0.0	0.0
Severe burn	0.0	0.0	0.0
Fracture/dislocation	60.6	0.0	0.0
Contusion/bruise	0.0	53.1	0.0
Abrasion	0.0	27.7	0.0
Complaint of pain	3.6	0.0	82.8
None visible	0.0	0.0	14.6
Unspecified	0.0	0.0	2.6
	100.0	100.0	100.0
Victims' Physical and Emotional Status			
Unconscious	5.4	0.0	0.0
Semiconscious	7.1	0.0	0.0
Incoherent	1.8	0.0	0.0
Shock	10.7	5.4	4.2
Conscious	75.0	94.6	95.8
	100.0	100.0	100.0

percent suffered some form of traumatic amputation. More than 5 percent of the victims were unconscious. For the 192 pedestrians sustaining C-level injuries, more than one-half sustained injuries to the hip, leg, or foot.

Summary

School Bus Accident Fatalities

Each year in the United States an average of 149 people are fatally injured in school bus-related accidents. Of those killed, 17.4 are occupants of school buses or vehicles used as school buses (12.0 student passengers, 3.0 adult passengers, and 2.4 drivers). The remainder are occupants of other vehicles (82.2), bicyclists (4.8), and pedestrians (44.6).

Of the 12.0 student passengers killed in an average year, 9.6 are riding in school buses, predominantly Type I school buses for which passenger seat belts are not presently required by federal standards. The other 2.4 are killed in some other type of vehicle being operated as a school bus (Table 3-25).

Accidents that result in school bus passenger deaths are typically frontal collisions involving other motor vehicles. These accidents appear to occur disproportionately during school-sponsored field trips on high-speed highways (Interstates and U.S. and state routes) after dark. Approximately one-third of the school buses in which fatalities occur overturn after colliding with another vehicle or a fixed object. Post-crash fires in these accidents are exceedingly rare. Between 1982 and 1986 no school bus passengers died from fire or smoke inhalation.

Of the 44.6 pedestrians killed on average each year in school bus-related accidents, 37.4 are students—24.0 are struck and killed by school buses, 1.8 are killed by vehicles operated as school buses, and 11.6 are killed by other vehicles (Table 3-25).

As might be expected, fatalities involving student pedestrians typically occur during mornings and afternoons, Monday through Friday. Afternoon fatalities outnumber morning fatalities about three to one. When a child is struck and killed by his own bus, the accident probably occurred on a local road. When a child is struck and killed by another vehicle, the accident probably occurred on a U.S. or state highway, or on a county road. Younger children are more likely than older children to be killed in pedestrian accidents. This is particularly true for accidents in which children are struck and killed by school buses. *More than one-half of all children struck and killed by school buses are 5 or 6 years old.*

TABLE 3-25 ESTIMATED ANNUAL STUDENT FATALITIES IN SCHOOL BUS ACCIDENTS (summarized from Table 3-2)

	Fatalities
School Bus Passengers	
School buses[a]	9.6
Vehicles used as school buses[b]	2.4
	12.0
Pedestrians	
Struck by school bus[a]	24.0
Struck by vehicle used as school bus[b]	1.8
Struck by other vehicle	11.6
	37.4

NOTE: Students defined as persons under 20 years old.

[a]"School bus" refers to a vehicle designed and built as a school bus, excluding van-based buses. These vehicles are predominantly Type I buses with GVWRs greater than 10,000 lb.

[b]"Vehicle used as a school bus" refers to a vehicle that is externally identifiable as a school bus, for example, station wagons, standard vans, and vans modified to serve as school buses.

[c]Excludes students killed in school bus accidents while riding bicycles or riding in other (nonschool-related) motor vehicles.

School Bus Accident Injuries

The total number of persons injured in school bus–related accidents each year may be as high as 19,000. The majority of these passengers sustain only minor or possible injuries. One-half of all school bus accident injuries are sustained by school bus passengers; 475 of these 9,500 injuries are incapacitating (A-level) injuries.

In addition to the estimated 9,500 students injured as school bus passengers each year, another 800 may be injured as pedestrians. The injuries sustained by pedestrians are typically more severe than the injuries sustained by school bus passengers; for example, 5 percent of school bus passenger injuries and 20 percent of pedestrian injuries are categorized as incapacitating. Furthermore, the incapacitating injuries sustained by pedestrians appear to be more severe than the incapacitating injuries sustained by school bus passengers.

Notes

1. Values of 1 (Yes) for variable A83 (school bus-related) were used to select the 642 school bus-related accidents in these analyses (NHTSA 1984, 85).

2. Values of 30 (school bus) for variable V18 (body type) were used to select the 484 vehicles designed and built as school buses (NHTSA 1984, 120).
3. Values of 2 (vehicle used as school bus) for variable V47 (special use) were used to select the 51 vehicles that were not designed and built as school buses, but were used as school buses (NHTSA 1984, 146). These 51 vehicles included the following body types: 34 vans, 8 other buses, 5 unknown buses, 2 truck-based station wagons, 1 intercity bus, and 1 transit bus.
4. All 60 of the fatally injured school bus passengers given in Table 3-1 were killed between 1982 and 1985. No school bus passenger fatalities were found in the FARS file for 1986. NHTSA confirms that there were no school bus passenger fatalities, as defined in this report, recorded in the United States in 1986. In 1987, however, NHTSA reports that 11 school bus passeng· rs were fatally injured.
5. One vel : struck and killed three pedestrians: two student pedestrians and a woman over 20 years old.
6. School bus drivers include drivers of any vehicles operated as school buses and externally identifiable as school buses.
7. A multivehicle accident is defined as any traffic accident involving two or more motor vehicles, including parked vehicles and vehicles not in operation.
8. Between 1982 and 1986, 294 (45.8 percent) of the 642 fatal school bus accidents recorded in the United States occurred in the 14 states listed in Table 3-17. If these states account for 45.8 percent of all school bus-related injuries, then in an average year it is estimated that there are 15,600 school bus accident injuries in the United States.

References

ABBREVIATIONS

NHTSA	National Highway Traffic Safety Administration
NSC	National Safety Council
NTSB	National Transportation Safety Board

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NSC. 1984. *Manual on Classification of Motor Vehicle Traffic Accidents.* Chicago, Ill.

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4 Measures To Enhance the Safety of School Bus Passengers

ON AVERAGE, 12 CHILDREN are killed and another 9,500 are injured each year while riding as passengers in school buses or vehicles operated as school buses. To reduce the number of fatalities and injuries that occur each year, a number of safety measures have been devised, and many have been implemented. These measures can be divided into two major categories: (a) crash-phase protective measures and (b) post crash protective measures. Crash-phase protective measures reduce the likelihood of death or injury to school bus passengers during a collision by (a) restraining or containing the occupant in the seating zone, and (b) distributing the load and managing the energy of occupant impacts. Post-crash protective measures are intended to expedite the evacuation of passengers or reduce the likelihood of fire and smoke after a collision.

In this chapter, three existing federal standards to protect school bus passengers during a collision are first reviewed: Federal Motor Vehicle Safety Standards (FMVSS) 220 (School Bus Rollover Protection), 221 (School Bus Body Joint Strength), and 222 (School Bus Passenger Seating and Crash Protection). Next, six proposed modifications to further protect school bus passengers during a collision are considered: seat belts (i.e., lap belts), lap bars, lap and shoulder belts, rear-facing seats, higher seat backs, and prohibition of standees. Seat belts, the safety device that Congress specifically cited in the study request, are reviewed in detail.

Included in the review of seat belts are estimates of the degree to which seat belts might reduce the likelihood of death and injury to passengers in Type I school buses. These estimates are based on studies of the effectiveness of seat belts in the rear seats of automobiles, full-scale school bus crash tests, sled tests, and analyses of school bus accident data. In addition, data from three surveys on seat belt use in Type I school buses that are equipped with seat belts are reviewed and discussed.

Finally, three existing federal standards intended to enhance the post-crash safety of school bus passengers are reviewed: FMVSS 217, 301, and 302. FMVSS 217 addresses the emergency exits required on school buses; FMVSS 301 and 302 address fuel system integrity and the flammability of interior materials, respectively. Modifications to these standards that might further enhance post-crash safety are considered.

Crash-Phase Protective Measures

Before specific aspects of school bus passenger protection are addressed, an overview of the concepts and theory of occupant crash protection systems may be helpful. In general, such crash-protection systems have three components: vehicle crashworthiness, friendly interiors, and restraint devices.

Structural integrity of the vehicle body is important for containing the occupant. In addition, crushable exterior structures, particularly vehicle front ends, absorb impact energy by lengthening the stopping time and distance of the passenger compartment and thus reducing the impact accelerations acting on the occupant. A crashworthy vehicle combines energy absorption with maintenance of occupant space. Energy absorption through crush is more effective in frontal than lateral crashes because of the greater crush distance available. For side impacts, deformation of the side structure should be minimized by deflecting the impact forces or spreading them over a broad area.

For unrestrained occupants, the vehicle collision and resulting deceleration are followed by the collision of occupants with the interior. During this second collision, unrestrained occupants continue to travel forward at the vehicle's precrash velocity until they strike the interior. A considerable degree of occupant protection can be achieved by using energy-absorbing interior structures that deform in such a way that the occupant's stopping time and distance are extended. The remaining impact forces should then be spread over the strongest parts of the occupant's body. The simplest method to achieve both energy absorption and load distribution is to surround the occupant with thick, slow-recovery foam padding. Such padding installed over deformable metal structures forms the basis for a friendly interior.

Further impact protection can be provided if occupants are restrained in the passenger compartment by seat belts or other restraints so that they can "ride down" the crash as the vehicle's front end or other energy-absorbing structures crush. Restraints not only allow the occupant to decelerate more slowly than padding allows, but they also reduce collisions among occupants, effectively distribute impact loads over the body, and provide significant control over occupants' motions during the wide range of impacts that can occur. Finally, restraints limit possible contacts with the interior of the passenger compartment and significantly reduce the risk of compressive neck injury in rollover crashes.

Existing Standards

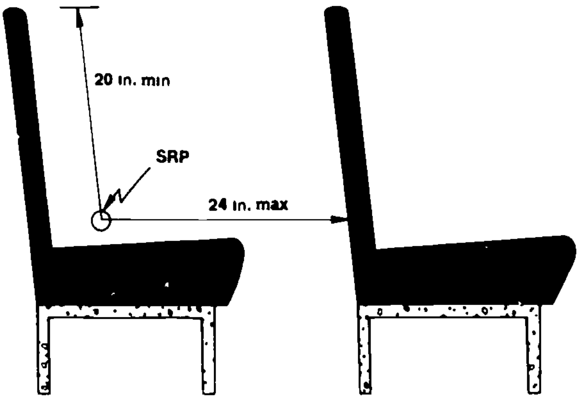
In 1977 the National Highway Traffic Safety Administration (NHTSA) issued three standards that were intended to enhance the safety of school bus passengers during a collision. The first of these standards, FMVSS 220 (School Bus Rollover Protection) (49 CFR 571.220), sets minimum strength requirements for school bus roofs and is intended ". . . to reduce the number of deaths and the severity of injuries that result from failure of the school bus body structure to withstand forces encountered in rollover crashes." Specifically, when a school bus roof is loaded with a force equal to 1.5 times the unloaded weight of the bus, in a manner prescribed by the standard, the roof must not collapse at any point by more than 5⅛ in. Furthermore, school bus emergency exits must remain operable (as defined in FMVSS 217) after school bus roof loadings are applied.

FMVSS 221 (School Bus Body Joint Strength) (49 CFR 571.221), which applies only to school buses with gross vehicle weight ratings (GVWRs) greater than 10,000 lb, is intended ". . . to reduce deaths and injuries resulting from the structural collapse of school bus bodies during crashes." Specifically, the standard states that when a body panel—an interior or exterior panel enclosing the passenger compartment—joins another body component, the joint will not come apart when a force equal to 60 percent of the tensile strength of the weaker material is applied. Body panels excluded from the provisions of this standard include "spaces designed for ventilation or another functional purpose, . . . doors, windows, and maintenance access panels."

Analyses of school bus accidents in the late 1960s and early 1970s revealed that one of the main hazards to school bus passengers involved in severe accidents, particularly rollover crashes, was the school bus body itself (NTSB 1970, Siegel et al. 1971, Davis 1977). School bus bodies are constructed of a series of steel panels joined to form the walls and ceiling of the bus. In severe collisions, the forces acting on the bus may cause these panels to separate, exposing sharp panel edges that can cause serious lacerations. By mandating stronger attachment of adjacent body panels, FMVSS 221 sought to reduce the frequency and severity of this type of injury.

Finally, FMVSS 222 (School Bus Passenger Seating and Crash Protection) (49 CFR 571.222) is intended to reduce serious injuries and deaths during school bus accidents through occupant restraints and passenger seat compartmentalization. For Type I school buses (buses with GVWRs greater than 10,000 lb), the compartmentalization requirements of the standard apply. Under these requirements all seat backs must be well padded and have a minimum back height; maximum longitudinal spacing between seats must not exceed 24 in., and seat backs, when loaded in a forward or rearward direction, must deflect according to a set of criteria.[1] For buses with GVWRs of 10,000 lb or less, seat belts are required at all seating positions. In addition, the compartmentalization requirements described also apply to these smaller buses; the only exceptions are those pertaining to seat spacing and restraining barriers.

Section 5.1 of FMVSS 222 requires that school bus seats face forward and be at least 20 in. high; that is, they must extend 20 in. above the seating reference point (SRP) as shown in Figure 4-1. The total area of the seat back above a horizontal line through the SRP must exceed 90 percent of the seat bench width, multiplied by 20. When loaded from the rear according to the



All measurements of school bus seat back height and spacing are from the seating reference point (SRP) Under the provisions of FMVSS 222, each manufacturer defines the SRP for its own seats

The SRP is based on the H-point as defined in the Society of Automotive Engineers' standard SAE J826 The H-point is the point about which the human torso and thigh pivot The SRP is the location of the pivot point (i e , H-point) of the human torso and thigh when seated on a school bus seat

Under the provisions of FMVSS 222, minimum seat back height is 20 in and maximum allowable spacing between seats is 24 in

FIGURE 4-1 Measurement of school bus seat back height and spacing.

prescribed procedure, the seat back must not deform more than 14 in or so much that the loaded seat fails to return to within 4 in. of the forward seat. The seat back must also absorb crash energy at a controlled rate when loaded from the rear. When loaded from the front, the seat back must not deflect to within 4 in. of the seat behind the seat back being tested.

Section 5.2 of FMVSS 222 includes an implied seat-spacing requirement by specifying the need for a barrier if there is no seat back surface within 24 in. forward of the SRP. Performance requirements for such barriers are given in §5.2.3. The provisions in 5.2 generally conform to the provisions in §5.1. It should be noted, however, that the provisions in §5.2 do not apply to buses with a GVWR of 10,000 lb or less.

Section 5.3 establishes criteria for cushioning the head and legs of school bus passengers during a crash. This section addresses the materials used in the construction of school bus seats and seat backs and prescribes two devices (a head form and a knee form) to measure the energy-absorbing qualities of the materials being tested.

Before the issuance of FMVSS 222, school bus seats were a major source of injury in school bus accidents. "It is probable that seats account for, or contribute to, over 90 percent of all injury in a . . . school bus impact" (Siegel et al. 1971, 324).

Although it is difficult to assess the benefits of the passive restraint provisions in FMVSS 222, the Center for the Environment and Man estimates (Northrop et al. 1980, vi):

> [S]eat back padding, higher se . backs, closer seats, stronger seat floor supports and seat frames, and the other requirements of FMVSS 222 are probably very effective (about 69 percent injury reduction) in the vast majority of school bus accidents, which usually involve minor damage to the bus, with at most a few passengers injured at the . . . [minor or moderate injury] . . . level. In the few violent school bus accidents that produce fatalities, FMVSS 222 has lower effectiveness—about 29 percent injury reduction. The Standard has only limited effectiveness in the extremely small subset of very violent accidents involving rollover, crashes with trains, etc., where passengers are thrown into contact with each other, and/or forcibly come into contact with broken glass, walls, roof, and other interior objects (which are not covered by the Standard), or are ejected from the bus.

On the basis of its review, the committee concludes that the three school bus safety standards issued in 1977 (FMVSS 220, 221, and 222) have been highly effective in reducing school bus passenger injuries.

Seat Belts (Lap Belts)

Seat belts are not a new safety device; they were first used in buggies before 1900 and in automobiles by the late 1940s. Lap belts and shoulder belts became standard equipment on all automobiles sold in the United States in 1964 and 1968, respectively.

Effectiveness of Lap Belts in Reducing Deaths and Injuries in Type I School Buses

To date there have been no statistical or epidemiological studies of the effectiveness of lap belts on Type I school buses because of the relatively small number of belt-equipped buses involved in accidents. Absent such data, all estimates of the effectiveness of lap belts on Type I school buses are based on analyses of automobile accident data, extrapolations from crash tests and sled tests, and clinical analyses of school bus accident data. In the next sections the findings of research in each of these areas are summarized, and a synopsis at the end of the section draws on the collective findings of these separate research approaches to develop an estimate of the likely effectiveness of lap belts on Type I school buses.

Rear Seat Lap Belts in Passenger Cars

A review of the literature on the effectiveness of seat belts conducted in the early 1970s concluded (Griffin 1973, 3-4):

> Lap belts reduce death and serious injury to drivers by 40 or 50 percent. For right front seat passengers the savings in deaths and serious injury is probably between 30 and 40 percent. For rear seat passengers savings due to lap belts are still less.

In considering the potential effectiveness of seat belts in reducing death and injury to school bus passengers, the literature on lap belt effectiveness in the rear seats of passenger cars was reviewed. Rear-seat occupants in passenger cars appear to face fewer threats to safety than do front-seat occupants, as do school bus passengers seated in large, Type I school buses (buses built since 1977). However, occupants of rear seats in passenger cars may be exposed to more severe or life-threatening crash conditions than passengers riding in post-1977 school buses. Because of their mass and high center of gravity, school buses have a distinct advantage over passenger cars in most traffic accidents, particularly multivehicle accidents involving passenger cars. In addition, along the routes that most school buses travel, buses are exposed to less hostile traffic and environmental conditions than are passenger cars. For these reasons, the effectiveness of lap belts in reducing injury to occupants of rear seats in passenger cars probably defines the upper limit of the benefits that might be realized from the use of lap belts on Type I school buses.

A recent analysis of accident data from North Carolina conducted at the Highway Safety Research Center for calendar years 1979–1985 showed a 46 percent overall reduction in fatal and severe injuries to rear-seat occupants who wore lap belts. When the analysis was restricted to frontal collisions, lap belts were shown to reduce fatal and severe injuries by 45 percent (Campbell 1986).

In a study based on 11 years of fatal accident data (1975–1985) from the Fatal Accident Reporting System (FARS), Evans estimated the degree to which fatally injured adult passengers (16 years old or older) riding in the rear seats of passenger cars benefited from the use of lap belts.

According to Evans' calculations, the use of a lap belt reduces by 18 percent the likelihood of death for rear-seat occupants involved in an accident. In frontal crashes Evans (1986) found no statistically significant reductions in fatalities attributable to lap belt use.

The National Transportation Safety Board (NTSB) concluded, after review of 26 severe frontal collisions, that rear-seat occupants in frontal collisions might not benefit from the use of lap belts and might incur additional injuries from the lap belt itself (NTSB 1986, 33). The NTSB study contradicts the findings of Campbell but complements the findings of Evans for frontal collisions. It should be pointed out, however, that the three studies were carried out on vastly different data sets using very different analytical procedures to assess lap belt effectiveness.

Campbell's estimates were based on injuries sustained by more than 35,000 belted and unbelted rear-seat occupants riding in passenger cars, vans, and light trucks manufactured after 1975. His estimates were statistically weighted to account for any differences in crash severity to which the belted and unbelted rear-seat occupants were exposed. Evans' data, on the other hand, included more than 10,000 crash-involved passenger cars that contained a fatally injured occupant and a rear seat passenger 16 years old or older. To estimate the degree to which lap belts might benefit rear-seat occupants, Evans compared the proportion of belted and unbelted rear-seat occupants killed in these accidents with the proportions of belted and unbelted occupants killed in the other seating positions. The NTSB's estimate that lap belts do not help, and may harm, rear-seat occupants is a clinical assessment of in-depth investigations of 26 frontal collisions that Campbell suggests are atypically severe.

The differences in the estimates of lap belt effectiveness provided in the previous three studies cannot be resolved without further research. In this study, however, more weight was given to statistical analyses of large, representative samples than to clinical extrapolations of small selected samples.

School Bus Crash Tests

Crash tests are conducted by propelling a test vehicle (e.g., a school bus) into a fixed or movable object or some other stationary or moving vehicle. Researchers conduct such tests to determine the structural integrity of the test vehicle during the crash and to assess the potential injury to vehicle occupants by studying the accelerations and forces on anthropomorphic dummies in the test vehicle.

UCLA Tests In 1967 Severy et al. published the results of three crash tests conducted on one large, Type I school bus at the University of California at Los Angeles (UCLA) (Severy et al. 1967). The test bus, a 1965 Superior Coach, 60-passenger vehicle built on a GMC frame, was struck three times:

1. *Head-on collision*. The 1965-model bus was struck head-on by another school bus (a 1944 Superior Coach, 60-passenger vehicle built on a Mack frame) traveling at 30 mph. The test bus (1965 model) was also traveling at 30 mph. Both buses weighed 17,500 lb.
2. *Rear-end collision*. The test bus was next struck from the rear by a 4,400-lb, 1960 Plymouth passenger car traveling at 60 mph. The bus was stationary before the collision.
3. *Side impact*. In a third test, the same test bus was struck on the side (at the rear axle) by a 4,500-lb, 1966 Chevrolet passenger car traveling at 60 mph. Again, the bus was stationary before the collision.

A number of independent factors were manipulated in these crash tests:

- *Anthropomorphic dummies*. Four different dummies were used: 3-, 6-, and 13-year-old and adult. Dummy weights ranged from 32 to 200 lb; heights ranged from 38 to 72 in.
- *Seats*. Eleven types of school bus seats, ranging from fairly standard to inflatable, were tested.

• *Restraints*. Conditions included no belts, lap belts, three-point harnesses, preinflated air bags, and restraint bars.

Different dummy–seat-restraint combinations were used throughout the nine rows of seats in the test bus. By varying these three factors among the nine rows of seats (by left and right side of the bus, and by aisle versus window seats), Severy et al. attempted to assess the likely injury severity of different types of school bus accidents on passenger safety as a function of passenger (dummy) size, type of seat, and type of restraint.

Thirty-nine anthropomorphic dummies were used in all three tests. Data were collected by using 61 transducers and 33 high-speed motion picture cameras. From the data collected, Severy et al. (1967) concluded

> 1. The backs of school bus seats should be at least 28 inches high.[2] High-backed seats (28 in. or more) greatly contribute to the compartmentalization of passengers, thereby reducing the chances of injuries sustained by passengers being hurled against one another, regardless of size.
>
> 2. Next in importance . . . [to a well padded, 28 in. seat back] . . . is the use of a three-point belt, a lap belt or other form of effective restraint.

Severy et al. (1967) are careful to point out, however, that the use of lap belts in conjunction with low-backed, inadequately padded seats typical of those installed in school buses before 1977 can increase injuries because ". . . the lap-belted passenger pivots about his belt and slams his head, face, and, if tall enough, his chest into the seat back ahead" (Severy et al. 1967).

In a second set of school bus crash tests conducted at UCLA, additional information was provided on school bus passenger protection (Wojcik and Sande 1972). In the first of the two crash tests conducted, a modified, 60-passenger, 1969 Superior Coach school bus was crashed head-on into a 2-ton dump truck. Both vehicles were traveling at 30 mph before the collision.

In the second test, the same school bus was struck on the side (at the rear axle) by a 1967 Ford sedan traveling at 60 mph. The school bus was stationary before the collision.

A number of independent factors, such as seat types, restraint types, and passenger (dummy) size, were again manipulated. Procedures for recording collision data, both electronically and photographically, were similar to those used in the first tests.

Wojcik and Sande (1972) support the finding from the UCLA tests conducted by Severy et al. that seat belts should not be used on conventional school bus seats with low backs and nonforgiving surfaces (e.g., pre-1977 standard school bus seats). However, the researchers do acknowledge that seat belts would be beneficial when used with seats with high, well-padded backs (Wojcik and Sande 1972, 147):

> For buses provided with safety seats having a performance profile comparable to the UCLA design, seat belts will contribute a significant measure of safety, especially during severe upset collision exposures. However, when safety seats are used, the authors regard further restraint measures, such as installation of safety belts, of minor importance, because of the special protection afforded to school buses by their size and conspicuity.

Acknowledging that seat belts used in conjunction with seats that have high, well-padded backs may be advantageous, particularly in an accident in which the school bus is overturned, Wojcik and Sande (1972, 146–147) state:

> The Series II head-on collision established that the average size school child (13-year-old) would sustain less head impact forces (44 g's versus 67 g's) if left unbelted than if lap-belted, provided he was protected by a 28-inch-high energy absorbing, UCLA-design seatback.

In effect, Wojcik and Sande argue that when lap belts are installed on school bus seats with high, well-padded backs, safety will be enhanced even though the head impact forces sustained by belted occupants in a 30 mph crash will exceed those of unbelted occupants.

Canadian Tests In a report published in January 1985 entitled *School Bus Safety Study,* Volumes I and II (TR 6222E), Transport Canada presents the results of three full-scale school bus crash tests performed on buses of three different sizes. Two of the buses had GVWRs of 10,000 lb or less and would, therefore, be required to be equipped with seat belts if sold in the United States. Of greater interest to this study was the test performed on the third bus, a 66-passenger, 1984 model, manufactured by Blue Bird Body Company on an International Harvester chassis with a GVWR of 25,000 lb. The actual test weight of the bus was 17,923 lb.

Located in three rows of the bus were six, fifth-percentile, female, instrumented anthropomorphic dummies and two, uninstrumented anthropomorphic dummies representing 6-year-olds.[3] (See Table 4-1 for position of dummies and the lap belt status and instrumentation associated with each dummy.)

Seat spacing for the three rows containing instrumented dummies (rows 1, 6, and 11) was as follows: Row 1, 21 in. (maximum seat spacing allowed in Canada); Row 6, 27 in. (a spacing that would counter the compartmental-

TABLE 4-1 SEATING POSITIONS AND INSTRUMENTATION FOR ANTHROPOMORPHIC DUMMIES USED IN THE TRANSPORT CANADA CRASH TEST

	Seating Position			Accelerometers		Femur Load
Instrumented[a]	Row[b]	Side	Lap Belt	Head	Chest	Cells
Yes	1	Left	No	Yes	Yes	No
Yes	1	Right	Yes	Yes	Yes	No
Yes	6	Left	Yes	Yes	Yes	No
Yes	6	Right	No	Yes	Yes	Yes
Yes	11	Left	No	Yes	Yes	Yes
Yes	11	Right	Yes	Yes	Yes	Yes
No	5	Left	No	No	No	No
No	5	Left	No	No	No	No

[a]All instrumented dummies were fifth-percentile females.
[b]There were 11 rows of seats in the bus.
SOURCE: Farr 1985b, Appendix E, 7.

ization concept of passive passenger protection); and Row 11, 24 in. (the current standard in the United States and the proposed maximum seat spacing in Canada).[4]

During the test, the bus was accelerated up to a velocity of 30.5 mph and guided head-on into a fixed concrete wall at an impact angle of zero degrees, that is, an angle of 90 degrees to the plane of the wall. Dynamic crush during the collision was approximately 54.0 in. Maximum static crush averaged 39.5 in. to the body of the bus and 12.1 in. to the frame. Despite the structural damage to the bus, the report notes that "... [t]here were no joint separations in the bus body. The integrity of the passenger compartment was maintained" (Farr 1985a, 64).

The results of the test are summarized in Table 4-2. Head injury criterion (HIC)[5] values of 649, 629, and 731 were recorded for the restrained dummies, and HIC values of 220 and 205 were recorded for the unrestrained dummies. Data for one unrestrained dummy (Row 1, left side) were invalid. Resultant chest accelerations for the three restrained dummies (40.8, 28.1, and 25.0 g's) were somewhat lower than the accelerations for the unrestrained dummies (60.4, 34.2, and 48.2 g's). Femur loadings were higher in the unrestrained dummies in Rows 6 and 11 (left femur 835 lb, right femur 525 lb; left femur 990 lb, right femur 980 lb) than in the restrained dummy in Row 11 (left femur 32 and right femur 50 lb).

As indicated in Table 4-2, the HIC values for the fifth-percentile, female, anthropomorphic dummies restrained with lap belts were consistently higher than those calculated for unrestrained dummies, although HIC values for all

TABLE 4-2 RESULTS OF A FRONTAL CRASH TEST ON A 25,000-LB (GVWR) SCHOOL BUS

Lap Belt	Seating Position Row	Seating Position Side	Seat Spacing (in.)	HIC[a]	Chest Acceleration (g's)[b]	Femur Loads (lb)[c] Right	Femur Loads (lb)[c] Left
Yes	1	Right	21	649	40.8	NR	NR
Yes	6	Left	27	629	28.1	NR	NR
Yes	11	Right	24	731	25.0	50	32
No	1	Left	21	—[d]	60.4	NR	NR
No	6	Right	27	220	34.2	525	835
No	11	Left	24	205	48.2	980	990

NOTE: NR indicates data not recorded.

[a]The Head Injury Criterion (HIC) is a measure of the degree to which a head or head form is assaulted during a collision. As can be seen from the following formula, HIC is a function of head acceleration during collision and the duration of that acceleration.

$$\text{HIC} = \left[\frac{1}{(t_2 - t_1)} \int_{t_1}^{t_2} a\,dt\right]^{2.5} (t_2 - t_1)$$

where t_1, t_2 = two points in time during the collision and a = resultant acceleration at the center of gravity of the head during collision, measured in g's (the acceleration of gravity). Times t_1 and t_2 are chosen to maximize HIC. HIC values greater than 1,000 are deemed unacceptable in motor vehicle safety standards issued by the United States and Canadian governments. For more detail see 49 CFR 571.222

[b]Chest accelerations are maximum resultant chest accelerations sustained for 0.003 sec, measured in g's. A resultant chest acceleration of more than 60 g's sustained for 0.003 sec is defined as unacceptable in motor vehicle safety standards in the United States and Canada.

[c]Femur loads in excess of 2,250 lb are unacceptable in U.S. and Canadian standards.

[d]Data lost due to technical problems.

SOURCE: Adapted from Farr 1985a, 51 and Farr 1985b, Appendix E.

five dummies are below 1,000—the critical value established by NHTSA (49 CFR 571.222). Review of high-speed motion picture film and accelerometer traces further revealed that restrained dummies were generally subjected to higher maximum resultant head accelerations, more sudden head accelerations, and more severe extensions of the neck than were unrestrained dummies.

From these observations, Transport Canada concluded (Farr 1985a, 7)

> The passive occupant protection of the seating system, required by federal regulation . . ., functions as intended during frontal impact and provides excellent protection for occupants.
>
> The use of lap seat belts in any of the 3 sizes of recent model school buses which were tested may result in more severe head and neck injuries for a belted occupant than for an unbelted one, in a severe frontal collision.

In a critique of this study Weber and Melvin question "the test procedures, the dummies, the significance of the measurements taken, and the validity of the judgements made . . . ." by Transport Canada.[6] More specifically, Weber and Melvin criticize the Canadian study on four points:

1. The fifth-percentile female dummies used in the Canadian tests roughly approximated the height and weight of 14-year-olds. Smaller dummies should have been used to represent younger children transported by school buses. Of the two dummies representing 6-year-olds in Test 1, one should have been restrained for purposes of comparison. (Presumably, both dummies representing 6-year-olds should have been instrumented.)
2. A HIC of 1,000, although appropriate for adults, may be too conservative for children, because children may be able to withstand higher head accelerations than adults. This point is acknowledged in the Canadian study and is reiterated in another critique of the Transport Canada study offered by John States.[7]
3. For the belted dummies, head accelerations (HICs) began when the dummies' heads were pivoted forward and hit the tops of the seat backs in front of them. The unrestrained dummies slid forward during the collision, which allowed their necks to hit the tops of the seats in front of them. Because of this motion, the unrestrained dummies experienced lower accelerations to the head (i.e., lower HIC values), but they may have experienced more damage to the neck. The dummies used in these tests were not equipped with transducers to record the trauma sustained by the neck.
4. The Canadian study indicated that the belted dummies were subjected to greater neck extensions (i.e., rearward bending of the neck) than were the unbelted dummies. This observation is at least partly a result of the test procedure. The dummies used in the Canadian tests were constructed with rigid upper torsos. When the belted dummies' heads hit the seat backs in front of them, bending of the upper body was transferred to the neck, producing an exaggerated, unrealistic picture of neck extension during impact. However, even the exaggerated neck extensions observed in the study were not "life threatening," as is claimed by the Transport Canada study.

Sled Tests of School Bus Lap Belts

Sled tests are conducted by rigidly fixing a portion of a motor vehicle—typically several passenger seats with specified restraint systems—to a sled that is rapidly accelerated or decelerated along a track. The accelerations and forces on anthropomorphic dummies placed in the seats are recorded and used to assess the injury potential for different seat and restraint systems.

In 1978 NHTSA conducted a series of sled tests to simulate the dynamics of school buses involved in frontal collisions (Bayer 1978). In five of these tests, the responses of four, 50th-percentile, male anthropomorphic dummies, two of which were restrained (lap belted) and two unrestrained, were compared. Three school bus seats were affixed to the sled, 20 in. apart. The front seat was vacant, the center seat held two restrained dummies, and the rear seat held two unrestrained dummies. Sled velocities were nominally 15 or 20 mph. The results of these tests (Table 4-3) indicate that although the performance measures for both restrained and unrestrained dummies were "acceptable," the unbelted dummies generally showed less severe head impact responses, but the study reported more direct loading on the neck and throat (Bayer 1978).

Clinical Analyses of School Bus Accident Data

Analyses of real-world accident reports have also been used to develop a better understanding of the effectiveness, or potential effectiveness, of seat belts in reducing the probability of death or the severity of injuries to school bus passengers. On April 12, 1984, a 1980-model, 64-passenger school bus was struck by a freight train on the right side immediately in front of the service door. During the collision, the school bus body and chassis separated completely. The bus overturned (270 degrees) and came to rest on its left side. The school bus driver was fatally injured, 2 passengers (a 10-year-old and a 14-year-old) were seriously injured, 1 passenger sustained moderate injuries, and the remaining 23 sustained minor injuries. None were ejected.

Commenting on the 10-year-old who was sitting in the first row behind the driver, the NTSB (1984, 28) concluded:

> This child sustained head trauma, including a depressed skull fracture. The installation and use of seat belt[s] by this child probably would have prevented or mitigated this injury.

A 14-year-old was sitting in the last row of seats on the right side of the bus. "Because of her size and initial seating position, the 14-year-old child sustained . . . basilar skull fracture when her head, which was above the padded seat back, probably contacted the frame of the emergency door at the right rear of the bus. . . . Use of a seat belt would not have prevented the 14-year-old's basilar skull fracture" (NTSB 1984, 28).

On September 14, 1987, a school bus operated by the Danbury (Connecticut) School District was involved in an accident that resulted in injuries to the driver and 22 of 23 passengers on board (22 students and one teacher aide).[8]

TABLE 4-3 SLED TESTS OF BELTED AND UNBELTED DUMMIES IN STANDARD SCHOOL BUS SEATS AT 20-IN. SPACINGS (Bayer 1978, 2-74, 2-76)

			Belted Dummies[a] (Center Seat)						Unbelted Dummies[a] (Rear Seat)					
			Left Side			Right Side			Left Side			Right Side		
Test No.[b]	Sled Speed (mph)	Acc. (g's)	HIC	CSI[c]	Chest Acc.[d]	HIC	CSI[c]	Chest Acc.[d]	HIC	CSI[c]	Chest Acc.[d]	HIC	CSI[c]	Chest Acc.[d]
37	14.9	3.55	181	45	21	155	48	23	77	27	18	116	24	16
38	14.8	8.43	226	50	18	156	44	16	259	63	25	233	48	[illegible]
39	14.9	8.63	175	55	27	155	62	30	107	22	17	87	15	13
40	14.8	8.48	321	50	21	499	61	25	128	23	15	183	36	19
41	[illegible]	10.32	447	117	51	465	88	30	201	59	29	184	58	31

[a]Fiftieth-percentile anthropomorphic, male dummies.

[b]The seats used in these tests were supplied by the following manufacturers: Test 37, Wayne; Test 38, Blue Bird; Test 39, Carpenter; Tests 40 and 41, Sheller-Globe.

[c]Chest Severity Index.

[d]Maximum acceleration in g's.

As the school bus attempted to make a left turn, it was struck on the left side by a dump truck. The bus, a 1981 model, was overturned by the impact of the dump truck. The damage sustained by the dump truck and the school bus is shown in Figure 4-2.

> Although the bus will be declared totalled for insurance purposes, it did appear to hold [up] very well in view of the force of the impact. It bent but did not break, which really was a positive factor in avoiding more serious injuries.[9]

The 23 passengers on the bus were seated in positions A through W, as shown in Figure 4-3. Circled letters represent belted passengers. The injuries sustained by the 12 belted and the 10 unbelted students (including the passenger of unknown belt status) are given in Table 4-4. "The seatbelts did not add to or subtract from the injuries."[10]

In Chapter 3, 26 school bus accidents that resulted in the deaths of 60 school bus passengers are analyzed. Additional information on each of these accidents is given in Appendix C. The brief narratives on each of these fatal

FIGURE 4-2 Damage sustained by a school bus and a dump truck in an accident in Danbury, Connecticut, September 14, 1987. *Photograph courtesy* Edward Hogan, Wayne Corporation, Richmond, Indiana.

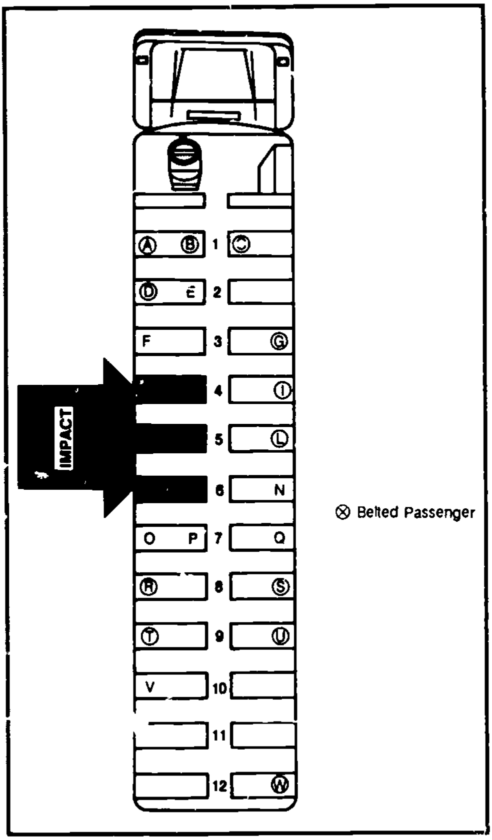


FIGURE 4-3 Seating positions and seat belt status of 23 school bus passengers involved in an accident in Danbury, Connecticut, September 14, 1987. [Data provided by Walter E. Skowronski (see end notes 8–10).]

accidents provide insight into how and why school bus passengers are fatally injured and suggest why the use of a lap belt may sometimes be of little or no benefit in reducing injuries or preventing fatalities.

Texas Transportation Institute School Bus Study Over a 10- r period (between 1975 and 1984) 19 school bus passengers were killed in separate accidents in Texas. Hatfield and Womack (1986) reviewed police officers' reports of these 13 accidents and attempted to estimate the degree to which seat belts would have reduced the number of fatalities. They were careful to

TABLE 4-4 INJURIES SUSTAINED BY SCHOOL BUS PASSENGERS IN DANBURY, CONNECTICUT, ACCIDENT

Belt Status	Seating Position	Description of Injuries	Date Returned to School
Belted	A	Neck strain, right shoulder strain, glass imbedded in right palm.	September 21, 1987
	B	Head and neck discomfort, bruise on right shoulder, glasses broken.	September 21, 1987
	C	Discomfort right shoulder, laceration right elbow.	September 21, 1987
	D	Discomfort right hip and side, both shoulders, bruises left hip and scrapes both arms.	September 17, 1987
	G	Passenger was an aide. No injury data available.	NA
	H	Bruise left knee, laceration of head and left index finger.	September 21, 1987
	I	Neck discomfort, bruises right leg, both shoulders, both hips.	September 21, 1987
	L	Discomfort right shoulder, laceration right hand (sutures).	September 15, 1987
	R	Discomfort left hip, pain through neck and left shoulder.	September 17, 1987
	S	Multiple lacerations back and sides (sutures), contusion right elbow.	September 17, 1987
	T	No apparent injuries.	September 25, 1987
	U	Neck discomfort, bruise right leg, scratches top of right foot.	September 17, 1987
	W	Contusion of forehead, neck and left hip discomfort.	September 15, 1987
Unbelted	E	Hematoma of head, neck discomfort, abrasion back and sides.	September 15, 1987
	F	Contusion right shoulder, hematoma of head, laceration right elbow.	September 16, 1987
	K	Bruise lower left leg, left shoulder and left upper arm.	September 21, 1987
	M	Discomfort through neck and both shoulders.	September 15, 1987
	N	Neck discomfort, right shoulder, mid-back and left chest discomfort, abrasions of right elbow, knee and back.	September 15, 1987
	O	Hematoma of head, bruise left shoulder.	September 21, 1987
	P	Pain through neck, left shoulder, right hip.	September 18, 1987
	Q	Discomfort left thigh and elbow.	September 15, 1987
	V	Laceration top of head, right side discomfort, left wrist.	September 18, 1987

NOTES: Accident occurred Tuesday, September 14, 1987. Passenger in seating position J was uninjured.

acknowledge that accident data taken from police reports lack the detail necessary to make such estimates. Police officers' narratives and additional information on the 13 accidents reviewed by Hatfield and Womack are given in Appendix D.

Of the 19 children killed, one was in a wheelchair and died in a noncrash event. Four were killed while out of position (one fell out of the bus and was struck by a moving vehicle; three had their heads outside bus windows and were struck by fixed objects). Hatfield and Womack (1986) suggest that the four children out of position would not have been killed had they been wearing seat belts. Of the 11 children killed inside school buses, 9 may not have been killed had they been wearing seat belts; in the case of two children, the benefits of seat belts were unclear. Of the three fatally injured children who were ejected from the buses, two might have been saved had they been wearing seat belts. It was unclear whether the third child would have been saved.[11]

Kyser questioned the reliability of Hatfield and Womack's assessments of the benefit of seat belts.[12] Kyser investigated Accident 5 (see Appendix D), which resulted in five passenger fatalities and about which Hatfield and Womack (1986, 48) state

> The head and multiple injuries sustained by the five victims, particularly the one who was ejected from the vehicle, would probably have been reduced had the occupants been wearing lap belts.

Commenting on the accident Kyser states

> I was on-site 24 hours after this accident. The bus was a 1976 bus. . . . The facts are that the body and chassis came completely apart and virtually no seat frame held to the floor.
>
> Neither the bus floor decking nor the seat frames had structural integrity sufficient to support seat belts.
>
> There was absolutely no evidence that could lead one to state that a lap belt would have lessened injury or [prevented] death in this accident.

Hatfield and Womack (1986) were unable to determine if a seat belt would have been advantageous in Accident 10 (Appendix D). Kyser states

> I and my associates were employed by the Houston Independent School District, and we provided the official investigation for the insurance carriers.
>
> The trailer was an unloaded flat-bed. The leading edge of the trailer, a "knife," literally sliced into the bus The child being in a seat belt would not have altered the outcome.

Finally, commenting on Accident 12 (Appendix D), Kyser again rejects the assumption that seat belts might have been advantageous:

> In discussion with those who actually investigated this accident, plus viewing the physical evidence; I would suggest that the *massive* compacting of the side and roof into the passenger compartment was the cause of death.
>
> Again, there was no evidence that could lead one to assume that a lap belt would have lessened injury or [prevented] death in this accident.

In a memorandum dated April 13, 1987, Hatfield again acknowledged that the information in police officer narratives is marginal at best for purposes of estimating seat-belt effectiveness in reducing passenger fatalities and that more detailed information of the type collected by Kyser and others would contribute to better estimates of seat-belt effectiveness.[13]

National Transportation Safety Board School Bus Study In 1984 the NTSB investigated a series of accidents involving Type I school buses manufactured after April 1, 1977. School bus accidents selected for in-depth investigation had to meet one or more of the following criteria (NTSB 1987, 9):

- The school bus was involved in a moderate-speed collision that disabled the bus (occupant injuries need not have resulted), or
- The school bus overturned, or
- One or more of the school bus occupants was seriously injured or killed in the accident (the accident could be of any type).

Forty-three accidents [involving 44 Type I buses (two Type I buses collided)] were investigated. In the 43 accidents, 13 school bus passengers were killed, 588 were injured (including those fatally injured), 563 sustained no injuries, and the injury status of 15 was unknown. Of the 44 school bus drivers involved in these accidents, 31 were injured (three fatally) and 13 sustained no injuries.

The severities of the injuries sustained by the 1,210 school bus passengers and drivers in the NTSB study and the accident configurations are given in Table 4-5. NTSB divided the school buses involved in accidents into two major categories: those that rolled over (90 degrees or more) and those that remained upright. The buses that did not roll over were subdivided into three categories by direction of impact: (a) front (including front angle) or rear impact, (b) side impact, and (c) multiple impacts. The buses that rolled over were further defined: (a) rollovers that followed collisions with other vehicles or fixed objects, and (b) rollovers that were not preceded by collisions.

TABLE 4-5 INJURIES (INCLUDING FATAL INJURIES) SUSTAINED BY SCHOOL BUS PASSENGERS AND DRIVERS

	Type of Accident					
	Nonrollover			Rollover		
Injury Severity[a]	Front or Rear	Side	Multiple	Collision	Noncollision	Drivers
Uninjured	333	125	6	53	46	13
AIS 1 minor	142	12	46	156	133	21
AIS 2 moderate	11	1	11	19	16	5
AIS 3 serious	4	0	1	17	2	3 (1)
AIS 4 severe	8 (5)	0	0	2 (1)	0	0
AIS 5 critical	4 (4)	0	0	1 (1)	0	2 (2)
AIS 6 maximum	0	0	0	2 (2)	0	0
Unknown	13	0	0	2	0	0
	515	138	64	252	197	44
Buses[b]	16	3	3	14	8	44
Fatalities	(9)			(4)		(3)

NOTE: Numbers in parentheses represent fatal injuries.

[a]Injury severity is defined by the Abbreviated Injury Scale (AIS) 1980 edition. When an individual sustained two or more injuries, the most severe injury is reported. Severity is scaled from minor injury (1) to maximum injury, virtually unsurvivable (6). However, fatally injured persons are not necessarily scored as a 6. Of the 16 fatally injured persons given in this table, only 2 received Level 6 injuries.

[b]Forty-four buses are given in this table Of the 43 accidents investigated, 1 involved the collision of two Type I school buses.

SOURCE: NTSB 1987, adapted from tables on pages 39, 41, 43, 46, and 48 and Appendix A.

Of the 1,166 passengers included in the statistics in Table 4-5, only 47 (4 percent) were restrained. This rate of restraint use is too small to allow for statistical comparison of the severities of injuries sustained by restrained and unrestrained passengers. Absent sufficient data to conduct a statistical analysis, NTSB examined the injuries sustained by all unrestrained passengers in the sample who received an Abbreviated Injury Scale (AIS) rating of 2 or more and the degree to which the use of seat belts might have decreased or increased fatalities and injury severity.

From its analyses, NTSB estimated that of the 13 fatalities in the sample, 2 would have been prevented had the passengers been wearing seat belts, 10 would have died even if they had been wearing seat belts, and for 1 passenger, the effect of a seat belt could not be determined. For injured survivors, the estimated effects of seat belts on injury severity are given in Table 4-6.

Four of the 86 survivors sustained AIS 4 (severe) injuries (Table 4-6). The injuries sustained by one of the four could have been reduced by the use of a

TABLE 4-6 ESTIMATED EFFECTS OF SEAT BELTS ON THE SEVERITY OF INJURIES SUSTAINED BY UNRESTRAINED SCHOOL BUS PASSENGERS (NTSB 1987, 78)

	Estimated Effect of Seat Belts				
Injury Severity	Reduced Severity	No Effect	Worsened Severity	Undetermined	Total
AIS 4, severe	1	2	1	0	4
AIS 3, serious	8	12	1	3	24
AIS 2, moderate	0	0	12	46	58
	9	14	14	49	86

NOTE: Only injured survivors are included.

seat belt; for two others, seat belts probably would have had no effect; and for the fourth, injuries might have been made worse by the use of a seat belt.

NTSB concluded that 8 of the 24 survivors who sustained AIS 3 (serious) injuries might have benefited from wearing seat belts, 1 might have been injured more severely, 12 would have been unaffected, and for 3, no determination could be made. Of the 58 survivors who suffered moderate injuries (i.e., AIS 2), 12 would have had their injuries aggravated by the use of seat belts; none would have benefited. The effect of seat belt use on the remaining 46 survivors who suffered moderate injuries could not be determined.

From its investigation, NTSB concluded that the installation and use of seat belts on Type I school buses are not warranted (NTSB 1987, 94):

> The Safety Board also does not recommend that Federal school bus safety standards be amended to require that all new large school buses be equipped with lap belts for passengers. The safety benefits of such actions, both in terms of reduced injuries for school bus passengers and in seat belt use habit formation, have not been proven.

Synopsis—Lap Belt Effectiveness

Review of the effectiveness of seat belts in reducing injury in school bus accidents was based on four types of studies: (a) inferences drawn from statistical evaluations of the effectiveness of seat belts in the rear seats of passenger cars, (b) crash tests (UCLA and Canada), (c) sled tests, and (d) analyses of real-world accidents.

Studies of the effectiveness of seat belts in reducing injuries to occupants in the rear seats of passenger cars suggest that seat belts may reduce the number of fatalities by 20 percent and serious and fatal injuries by 40 percent.[14]

The crash tests and sled tests reviewed by the committee did not suggest that seat belts (lap belts) would or would not be effective in frontal collisions. However, there were relatively few crash tests and sled tests available for the committee to review. Furthermore, the validity of some of the tests was questionable because of the instrumentation employed and the biofidelity of the dummies used. Dummies restrained by lap belts in both the crash tests and the sled tests sustained higher HIC values and lower chest g's than did comparable unbelted dummies. However, the HIC values recorded for both belted and unbelted dummies were consistently within the acceptable range. Had additional crash test and sled test data simulating side impacts and rollovers been available, the benefits of seat belts might have been more apparent.

Finally, the in-depth analyses of the effectiveness of seat belts in severe school bus crashes (e.g., NTSB study, suggest little if any benefit attributable to seat belt use. However, only a small number of cases were reviewed in these analyses, and the methodology was subjective.

From its review, the committee concludes that seat belts, when properly used on large, post-1977 buses, are not inherently harmful and that they may reduce the likelihood of death of or injury to passengers involved in school bus crashes by up to 20 percent. The potential benefit to be realized from the use of seat belts in school buses is somewhat less than the benefit afforded rear-seat occupants in passenger cars because the greater mass and safer operating conditions of school buses reduce the initial risk of death of and injury to school bus occupants. On the other hand, fewer belt-induced injuries can be expected to the abdomen of children using properly adjusted seat belts on firm school bus seats, as compared with the softer seats in passenger cars, because of better belt fit and the reduced potential for submarining.

Operational Experience of School Districts That Have Used Seat Belts on Type I Buses

Although the effectiveness of seat belts in reducing the probability of death and the severity of injuries in school bus accidents is of paramount importance, other questions must be considered:

- Will students riding in buses equipped with belts use them?
- Will the use of seat belts on school buses improve student behavior and reduce driver distractions?
- Will the use of seat belts on school buses encourage children to use belts in passenger cars?

Transportation Research Board Survey

A survey that posed similar questions was sent in Fall 1987 to 24 school districts in the United States that have operated Type I school buses equipped with lap belts. Of the 16 districts that responded, most were pleased with their seat belt programs; a few were not. The most objections to installing seat belts on Type I school buses were raised by the Fairfax County (Virginia) School District. Brief summaries of the responses from the Fairfax County School District, in addition to representative school districts in Illinois, New York, New Jersey, and Arizona are presented in the following paragraphs.

Fairfax County, Virginia In January 1986 Fairfax County Public Schools equipped 70 of its 64-passenger school buses with seat belts. By October 1987, 193 additional buses had been equipped with seat belts. These 263 buses, all owned and operated by the district, travel an average of 19,199 mi each school day to transport 25,248 pupils. Seat belt use is optional and is estimated to be less than 20 percent. Although the district acknowledged that seat belts may improve passenger behavior and that the use of seat belts as weapons is only a minor problem, vandalizing of the seat belts and theft of the buckles have been major problems. "Hundreds of belts have already been replaced, over 500 in the last two months alone."[15] The cost to replace a seat belt is $15 to $18, including labor and materials.

Skokie, Illinois Fairview School District 72 began using seat belts on its four 71-passenger school buses in September 1984. The four buses operated by the district travel approximately 14,000 mi (3,500 mi per bus) each year to transport 555 students to and from school. In addition to the driver, each school bus is staffed with a monitor who assists younger children (4- to 5-year-olds) in buckling and adjusting their seat belts. Seat belt use is 100 percent. The district reported no instances of seat belts being used as weapons, or to trip other students. No mention was made of seat belt defects or of students' vandalizing belts or buckles.[16]

Comsewogue, New York In 1983 the Comsewogue School District began requiring seat belts on all 30 Type I school buses serving the district. All 30 buses are operated by a private contractor and travel approximately 330,000 mi (11,000 mi per bus) each year to transport 3,500 children to and from school. In describing seat belt use, the district reported: "We experience no difficulty with the younger children except for having some trouble adjusting belts which are not of standard configuration; but we have occasional problems with the upper grade students." Although seat belts tend to improve student behavior, some belts have been vandalized. However, fewer than 3 percent of the 1,800 to 1,950 seat belts in the fleet have been vandalized.[17]

West Orange, New Jersey The Board of Education for West Orange, New Jersey, schools contracts for pupil transportation services. Since September 1983, 26 Type I buses equipped with seat belts have been used in West Orange. These buses travel approximately 338,000 mi per year to transport 2,000 children to and from school. The board of education reported that more than 95 percent of all students use their seat belts and that the use of seat belts has improved student behavior. Seat belts and buckles have not been used to trip other students, nor have they been used as weapons. "Since installation in 1983, only one belt has been vandalized."[18]

Marana, Arizona The Marana Unified School District operates 61, 84-passenger, Type I school buses (5 buses for handicapped students) on 243 daily routes. The buses travel 5,500 mi per day to transport 4,000 children to and from school. The district began purchasing buses equipped with seat belts in 1985. To date, 7 buses that transport 280 to 350 students per day have been equipped with belts. The district reported, "There are always a few growing pains when students are first introduced to seat belt-equipped buses. However, we do have the backing of both the Administration and the Board of Education, which makes their use mandatory." No mechanical problems were reported with the seat belts, and vandalism was considered a very minor problem with only one seat belt having been vandalized.[19]

NHTSA Study

In 1985 NHTSA sponsored an informal survey of nine school districts that were operating school buses equipped with seat belts (Gardner et al. 1986). Survey techniques involved the use of telephone interviews, personal interviews, and group discussions. School district superintendents and administrative policy makers, transportation directors, bus drivers and monitors, and parents and students were surveyed. In addition, project staff conducted limited field investigations of student behavior on school buses equipped with seat belts and school buses without seat belts. From survey responses and behavioral observations, the researchers reached the following conclusions about seat belt use on belt-equipped buses (Gardner et al. 1986, 25):

> Some school districts with "hands-on" bus belt training and early onboard monitoring reported to have achieved high usage rates fairly early after belt programs began. In other cases with little belt education and training, belt use rates increased slowly. One jurisdiction did not achieve a 75 percent use rate for more than seven months—until a state law required car belt use and school officials finally threatened to enforce effective penalties.

With regard to student conduct on belt-equipped buses, the researchers concluded that seat belts were beneficial. This finding was based on interviews with drivers and students and behavioral observations (Gardner et al. 1986, 16):

> While riding on several bus runs, one field investigator noted that students on belt-equipped buses were seated and not roaming the aisles or standing on the seats, as were students on the unequipped buses. In two other instances, the investigator could distinguish between the belt-equipped and the unequipped buses lined up in front of the school by observing the behavior of the students on the buses.

As a corollary to the finding that seat belts improve student behavior, Gardner et al. (1986) suggest (on the basis of interviews with bus drivers) that seat belt use reduces driver distractions. Students restrained by seat belts are less likely to misbehave and to draw the driver's attention. Drivers who had driven both belt-equipped buses and buses unequipped with belts reported that they spent more time admonishing students on buses unequipped with belts (Gardner et al. 1986, 17).

Although the exact number of school bus–related accidents caused by driver distractions is unknown, a study conducted at the University of North Carolina suggests that somewhere between 1.5 and 5 percent of school bus–related accidents result from distractions to bus drivers (Lacey et al. 1980, 59).

Finally, the belief that a child who establishes the habit of wearing a seat belt on a school bus will be more likely to wear a seat belt in a passenger car (the "carryover effect") led the researchers to conclude (Gardner et al. 1986, 16):

> In the absence of clear habit formation and in the presence of such factors as classroom education, parental rules, and state mandatory use laws, any direct carryover effects of school bus belt use to belt use in cars were not apparent in the nine study sites.

New York Association for Pupil Transportation Survey

In March 1988, the New York Association for Pupil Transportation published the results of a survey of 771 school districts in the state of New York. The association received 502 (65 percent) responses.[20]

The survey results revealed that although New York law requires that school buses purchased after June 30, 1987, be equipped with lap belts, only 42 districts (8.4 percent of districts responding) indicated that the school boards in their district had adopted policies requiring the use of seat belts. Of the 42 districts that have formally mandated seat belts, the following levels of seat belt use were reported: 0 to 25 percent, 27 districts; 26 to 50 percent, 4 districts; 51 to 75 percent, 5 districts; 76 to 100 percent, 6 districts.

Synopsis—Operational Experience with Lap Belts

From its own survey, as well as published and informal studies on the use of seat belts in Type I buses, the committee concludes that if all Type I school buses were equipped with seat belts, roughly one-half of all passengers would use them. However, considerable variability exists in seat belt use rates among school districts with some reporting rates as low as 20 percent (Fairfax County, Virginia) and others reporting rates approaching 100 percent (Skokie, Illinois). If seat belts had been routinely available in school buses, and if seat belt use had been rigorously enforced, higher average use rates might have resulted.

Available research and surveys suggest that the use of seat belts in school buses may improve student behavior and reduce driver distractions somewhat. Regarding the carryover effect—whether seat belts in school buses encourage children to use seat belts in other contexts such as in the rear seats of passenger cars—no conclusive evidence exists.

Lap Bars

As an alternative to lap belts, at least two companies have recently undertaken the development of a lap bar restraint system similar to the one tested by Severy et al. in 1967. In the typical design, the padded bar is attached to the sides of the seat back in front of the passenger(s) being protected. A single bar would span the width of a two- or three-passenger seat and would be pulled down by the occupants. In a frontal collision, the passengers would move forward and rotate around the bar (theoretically) at the lower pelvis. As the bar is loaded by the passengers, the seat back is pushed forward, thus reducing or possibly eliminating the contact forces between the passengers' heads and the seat back in front of them. Proponents of lap bars also claim that this restraint system would be more likely to be used than seat belts, because it would be visible to the driver in the up or nonuse position.

The committee reviewed test results of such systems[21] and concluded that this approach to occupant restraint in school buses has three basic problems. First, a bar that is pushed against is inherently unstable and will be driven upward or downward by the passenger during loading, depending on the height and design of the bar's anchorage to the seat. This instability and potential poor positioning could result in intrusion injuries to the upper abdomen, fractures of the lower spine, or crushing injuries to the upper legs. In contrast, a belt placed properly across the lower pelvis will remain in that position and passively follow the direction of body movement. Second, one bar must restrain two or three passengers of different sizes, which merely complicates the problem of locating the bar in an optimum position relative to the pelvis. Finally, there would be no lateral hip restraint of individual passengers to provide containment and reduce collision between occupants in a side or oblique impact.

Lap and Shoulder Belts and Rear-Facing Seats

In 1986 Transport Canada conducted a series of sled tests on six school bus seat and restraint systems (Farr 1987). The tests were conducted to develop seat and restraint systems that had the potential to increase occupant protection for school bus passengers. Five developmental seat and restraint combinations were tested, along with a standard seat and lap belt combination that served as a baseline for comparisons (Table 4-7). Each test in the series involved two school bus seats mounted on a platform attached to a sled. One seat was mounted approximately 21 in. in front of the other, as measured from the SRP. Two fifth-percentile, female anthropomorphic dummies were used in each test—one in the front seat and one in the rear seat.

Each of the six seat and restraint combinations was tested in two collision modes: (a) head-on and (b) oblique; that is, 30 degrees from head-on. Two tests were conducted for each combination of seat and restraint and for each mode; that is, 24 sled tests were conducted. Each test had an input acceleration of 30 *g*'s and reached a nominal maximum velocity of 30 mph.

The results of the tests are summarized in Table 4-8. As the data indicate (Table 4-8), both the three-point and multipoint belts reduce HIC levels in frontal impacts and, to a lesser degree, in oblique impacts when compared with the standard seat and restraint combination. However, chest accelerations

TABLE 4-7 SEAT AND RESTRAINT COMBINATIONS USED IN THE TRANSPORT CANADA TEST SERIES

Condition[a]	Type of Seat Belt	Seat Facing	Seat Structure
1	Lap	Forward	Standard
2	Lap	Forward	Tops of the seats were fitted with additional energy-absorbing foam
3	Lap	Forward	Horizontal bars framing the tops of the seat backs were weakened so that they would deform on impact
4	Three-point	Forward	Structural strength of the seats was enhanced to carry the additional load from the upper torso
5	Multipoint	Forward	Structural strength of the seats was enhanced to carry the additional load from the upper torso
6	Lap	Rearward	Height of the seat backs was increased by approximately 10 in.

[a]Condition 1 was used as the baseline.

TABLE 4-8 TRANSPORT CANADA TEST RESULTS (Farr 1987, 23)

	Head-on Impact		30-deg Oblique Impact	
Condition	HIC	Chest Accelerations[a] (g's)	HIC	Chest Accelerations[a] (g's)
1 Standard seat	1,116.6	58.9	1,181.4	79.8
2 Padded seat	1,082.0	71.6[b]	1,154.9	68.2
3 Deformable seat	1,079.8	48.6	1,423.8	65.0
4 Three-point belt	634.0	60.3	917.6	72.2[b]
5 Multipoint belt	558.8	65.3[b]	834.5	68.7[b]
6 Rear facing	275.6	35.1	309.2	35.4

[a]Acceleration refers to peak resultant acceleration.
[b]Chest acceleration did not meet U.S. or Canadian standards; acceleration exceeded 60 *g*'s for more than 0.003 sec.

are unacceptable for the three-point belt in oblique impacts and for the multipoint belts in both head-on and oblique impacts.

One problem with the added structural strength that must be designed into school bus seats to accommodate shoulder belt systems (three-point and multipoint belts in this study) is that it makes the seats less flexible and, therefore, potentially more hazardous to unrestrained occupants (Farr 1987, 19):

It must be emphasized that if seats with lap and shoulder belts are installed in buses, it is imperative that the belts be worn at all times. Otherwise, any injuries due to unrestrained occupants striking the seat back would be more severe than with an existing seat due to the increased seat rigidity.

A second potential problem with equipping school buses with upper-body restraints was pointed out in the first series of UCLA school bus crash tests (Severy et al. 1967). Because school buses transport passengers of widely varying statures (e.g., 4-year-olds and adults), it would be difficult to anchor the upper end of the restraint system in a manner that would easily and effectively accommodate the range of passengers for which it is intended.

Of the five modified seat and restraint systems considered, the one that appeared to offer the most potential was the rear-facing seat with the higher seat back and lap belt. The HIC values recorded for the dummies in the rear-facing seats were well below the values recorded in all other test conditions (Table 4-8). The recorded HIC values for the head-on and oblique impacts were 275.6 and 309.2, respectively (compared with 1,116.6 and 1,181.4 for the forward-facing standard seat and lap belt combination). The recorded peak resultant chest accelerations for the dummies in the rear-facing seats were also well below levels recorded in the other seat and restraint combinations tested. The peak resultant chest accelerations recorded for other rear-facing dummies in the head-on and oblique impacts were 35.1 and 35.4 *g*'s, respectively. Comparable readings for the lap-belted, forward-facing dummies in standard seats were 58.9 and 79.8 *g*'s.

Partly from the results of these sled tests, the Canadian government began a demonstration program that involved three school buses equipped with rear-facing seats.[22] The buses were operated in four cities during the 1987–1988 school year. Each school district using the buses was asked to record acceptance of, and attitudes toward, the rear-facing seats, as well as any other pertinent information from students or parents that might aid in the evaluation of the system.

Discussions with representatives of Transport Canada indicate that the two major concerns associated with rear-facing seats—motion sickness and pupil management—did not become significant problems. Although some of the older children complained of motion sickness when riding in rear-facing seats, the younger children did not, which suggested that rear-facing seats might be phased into school bus fleets beginning with buses serving elementary grades (telephone conversation with William Gardner, Transport, Canada, November 22, 1988).

Any decision on the advisability of installing rear-facing seats in school buses should await the published findings from the Canadian field tests, and, if the Canadian results appear to be promising. additional field testing and evaluation should be conducted in the United States.

Seat Back Height and Spacing

Current federal standards require that the backs of school bus seats be at least 20 in. above the SRP (see Figure 4-1) (49 CFR 571.222). The first series of UCLA crash tests indicated that seat backs should be at least 28 in. high (i.e., 24 or 25 in. above the SRP) (Severy et al. 1967).

Arguments favoring a higher seat back are (a) if a bus is struck from the rear, higher seat backs will provide an added measure of safety by reducing hyperextensions of the neck, particularly for larger, taller passengers, and (b) if a bus is involved in a frontal collision, higher seat backs will reduce the likelihood that passengers thrown forward in their seats (with or without lap belts) will strike the top of the seat back in front of them, or override the seat back in front of them and strike other passengers.

Opponents of higher seat backs suggest that current standards are adequate and that to the extent that higher seat backs would add an additional measure of safety, that advantage is more than offset because higher seat backs block the driver's view of school bus passengers and, thereby, contribute to pupil management problems. Furthermore, if the height of school bus seat backs is raised to a point above the lower edge of side windows, the seat backs may be an obstacle to emergency window exits—an obstacle that may be prohibited under certain provisions of FMVSS 217, the standard that governs emergency exits on school buses.

Before requiring a minimum school bus seat back height 20 in. above the SRP, NHTSA sponsored a study to consider the safety implications of seat backs of different heights. In this study, manufacturer-supplied school bus seats, with backs of 24, 22, and 20 in., were tested on a sled to simulate frontal collisions at velocities from 10 to 20 mph. Three seats were mounted on the sled for each of the nine tests performed. In the center seat were two 164-lb, 5 ft 10-in. 50th-percentile male dummies. In the rear seat was a dummy representing a 6-year-old. The front seat was vacant (Adams 1975).

The HIC and chest decelerations recorded in all nine tests were within the acceptable range defined by NHTSA (49 CFR 571.222) (Table 4-9). The tests did show, however, that in the frontal impacts, 50th-percentile male dummies tended to "stand up" as their knees struck the seat back in front of them and their head and torso rotated forward and upward. Lower seat backs exaggerated this tendency for the dummies to stand up.

The study concluded (Adams 1975, 16):

> The effects of seat back height were found to be not particularly significant in frontal impacts, accept [except] in aggravating the "standing up" problem, which in turn is caused by improper phasing. The major consideration in determining correct seat back height may be one that was not addressed in this study: the whipping of the head over the top of the seat back in rear impacts.

In adopting a minimum seat back height of 20 in., NHTSA recognized that higher seat backs might afford school bus passengers additional protection:

> While the NHTSA does not dispute that a properly constructed higher seat back provides more protection than a lower seat back, the data support the agency's determination that the 20-inch seat back provides a reasonable level of protection.[23]

Although there may be some operational difficulties inherent in the use of higher (e.g., 24 in.) school bus seat backs, two states (New York and Illinois) now require them and report no operational problems or difficulty in complying with the NHTSA standard governing emergency exits. The reductions in passenger injury that might result from higher seat backs are difficult to assess because there are no real-world data to measure the effectiveness of higher seat backs in reducing injuries. Despite the absence of any real-world data, the committee believes that higher seat backs (24 in.) would probably reduce the number of school bus passenger deaths and injuries.

In another series of sled tests, the effect of seat spacing on potential passenger injury was assessed (Bayer 1978). In these tests standard school bus

TABLE 4-9 SLED TESTS CONDUCTED WITH 24-, 22-, AND 20-IN. SEAT BACK HEIGHTS (Adams 1975, 6, B-102)

Test No.	Seat Back Height (in.)	Sled Speed (mph)	Left Center Passenger[a]		Right Center Passenger[a]		6-Year-Old Child	
			HIC[c]	CSI	HIC[c]	CSI	HIC[c]	CSI
1	24	11.5	74	23	71	24	67	13
2	24	16.8	131	35	101	51	108	41
3	24	18.9	130	35	88	40	110	57
4	24	11.8	61	31	68	34	47	18
5	22	14.0	111	53	96	46	122	36
6	22	20.4	130	57	100	36	236	117
7	22	12.9	57	21	56	24	62	24
8	20	16.2	88	47	56	39	115	51
9	20	19.6	107	57	78	51	120	101

[a]Fiftieth-percentile male, Hybrid II dummy.
[b]Dummy representing 6-year-old supplied by NHTSA contractor that performed tests.
[c]Denotes results obtained from data filtered at Class 60 to eliminate ringing.

seats provided by school bus manufacturers were mounted on a sled. Three seats were mounted to a sled: two 50th-percentile male dummies were seated in the center seat; a dummy representing a 6-year-old was seated in the rear seat. The results of 18 sled tests are shown in Figure 4-4. The dependent response variable, HIC, is shown as a function of seat spacing (20, 22, and 24 in.), sled speed (15 or 20 mph), and seat manufacturer (o, •, +). There are 36 data points in Figure 4-4: HIC values were recorded for both 50th-percentile male dummies in each of 18 tests.

From the figure it is apparent that seat spacing (20, 22, or 24 in.) has little if any effect on head injury as measured by the HIC. Sled speed (15 or 20 mph), as might have been expected, covaries positively with HIC; that is, recorded HIC values are generally higher at 20 than at 15 mph. Most conspicuously, however, HIC covaries with manufacturer. The seats provided by one manufacturer [indicated by a plus sign (+)] are associated with the highest recorded HIC. Of the three manufacturers shown in this figure, the one with the highest HIC (+) was also the one with the highest seat backs. This finding

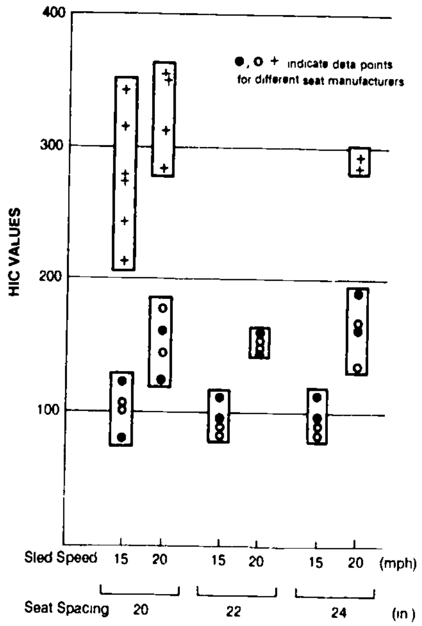


FIGURE 4-4 HIC values recorded in 36 sled tests as a function of sled speed, seat spacing, and seat manufacturer (Bayer 1978).

emphasizes that any attempt to characterize the safety of school bus seats by a single factor (e.g., seat back height or seat spacing) is overly simplistic.

The relative safety of a school bus seat is a function of several variables acting in concert. Among the variables of consequence are seat back height, spacing, padding, deformation characteristics, and the use or nonuse of a lap belt, in addition to the size and physical attributes of the dummy used in testing and the index (e.g., HIC, maximum chest acceleration, etc.) by which the performance of the seat is assessed.

Standees

In 1977 NHTSA issued FMVSS 222 (School Bus Passenger Seating and Crash Protection) to enhance the crashworthiness of school bus seats and to compartmentalize and protect school bus passengers in the event of an accident. Several states and many local school districts are now ordering Type I buses that exceed the requirements in FMVSS 222, for example, buses equipped with seat belts and 24-in. seat backs. Still other school bus seat and restraint systems (e.g., lap and shoulder belts, rear-facing seats) are in various phases of research and development and may become options.

School bus passengers must be seated, however, if current school bus seats, or optional seat and restraint systems, are to be effective in protecting them. Although no studies have estimated the added risk quantitatively, students standing in the aisle (i.e., standees) during a crash certainly suffer unnecessary injuries and endanger others when they are thrown about the passenger compartment. Several states have prohibited school bus operators from allowing passengers to stand in the aisle (NSBTA 1984, 9).

Structural Integrity

In addition to mandating minimum performance standards for school bus passenger seats in 1977, NHTSA issued two other "structural integrity" standards (FMVSS 220, School Bus Rollover Protection and FMVSS 221, School Bus Body Joint Strength) that have been beneficial in reducing the number of school bus passenger deaths and injuries. Nevertheless, from the review of the fatal accidents described in Appendix C—accidents that resulted in school bus passenger deaths—further improvements to the structural integrity of school buses may yet be made. Several of the cases reviewed in Appendix C involved post-1977, Type I buses that apparently sustained severe structural damage, with corresponding violation of the integrity of the passenger compartment (e.g., Cases 6, 8, 10, 12, 13, 19, 20, 21, and 25). In some of these crashes (e.g., collisions with tractor semitrailers or massive fixed objects), further improvements to the structural integrity of the bus may have been of little or no benefit. In other cases, however, structural enhancements such as placing a perimetric frame around the body of the bus or making less hazardous those body panels that are now exempt from the provisions in FMVSS 221 (e.g., ventilation spaces, access panels) might have reduced the likelihood of death and the severity of injuries sustained. The potential benefits and costs of various measures to improve the structural integrity of school buses are currently unknown but are worthy of further consideration.

Reflective Markings on School Buses

School bus accidents occur predominantly during daylight hours, with only about 4 percent occurring between the hours of 6:00 p.m. and 6:00 a.m. (Table A-7). Between calendar years 1982 and 1986, however, 5 of 26 (19 percent) accidents that resulted in fatal injuries to school bus passengers occurred between 6:00 p.m. and 6:00 a.m. Twenty-two of 60 (37 percent) fatally injured school bus passengers were involved in accidents that occurred during these hours (Table 3-8, Chapter 3).

Because school bus accidents that result in passenger fatalities appear to occur disproportionately during hours of darkness, making school buses more visible at night is one potential means of reducing these accidents and the fatalities that result.[24] During a demonstration of the use of retroreflective materials on the exterior of an operational school bus, the committee observed that school bus visibility can be dramatically upgraded through the application of such materials. However, no evidence is available to demonstrate the effectiveness of these materials in reducing school bus accidents. Further consideration should be given to the cost and effectiveness of retroreflective materials in reducing school bus accidents and the deaths and injuries that result from those accidents.[25]

Post-Crash Protective Measures

Vehicle Evacuation

FMVSS 217 (Bus Window Retention and Release) is intended "to minimize the likelihood of occupants being thrown from the bus and to provide a means of readily accessible emergency egress" (49 CFR 571.217). Under the provisions of this standard, all school buses must be equipped with one emergency exit that must meet prescribed size and operational characteristics. At the manufacturer's option, the emergency exit may be located at the rear of the bus, or on the left side in the rear half of the bus. If the manufacturer locates the emergency exit on the left side of the bus, a "push-out" window must be installed in the rear of the bus. Conventional school buses with front engines are typically equipped with rear emergency exits whereas transit-type school buses with rear engines are equipped with a left-side emergency exit and a rear push-out window. For school buses with left-side emergency exits, there is no prohibition against placing a passenger seat in the path of the exit, and manufacturers typically install a seat in this location.[26]

Although the number of emergency exits on transit buses is defined as a function of seating capacity (49 CFR 571.217 §5.2), this is not the case for school buses. Whether a school bus is designed to carry 20 or 90 passengers, only one emergency exit is required in addition to the right-front service door.

During this study no research was found that measured the benefits that might result from installing additional emergency exits or push-out windows on school buses. Recognizing that added emergency exits (particularly push-out windows) might increase the risks of ejection during a crash, especially during rollover crashes, the committee searched for research on this issue as well but none was found.

Regardless of the number or type of emergency exits installed on school buses, all school bus passengers must be properly trained in vehicle evacuation. NHTSA currently recommends that school bus evacuation drills be conducted at least twice each school year (NHTSA 1974).

Post-Crash Fires

Post-crash fires in school bus accidents are rare. During this study, no evidence was found of *school* bus accident fatalities that resulted from fire or smoke inhalation. Nevertheless, the *church* bus crash and post-crash fire in Carrollton, Kentucky, May 14, 1988, that involved a pre-1977 bus and resulted in the deaths of 27 bus passengers serve as a grim reminder that post-crash fires can and do occur in bus accidents.

Two standards (FMVSS 301 and 302) have been issued to reduce the probability of post-crash fires in school buses. FMVSS 301 addresses the integrity of the fuel system (49 CFR 571.301). This standard requires that a Type I school bus (GVWR greater than 10,000 lb) must be able to absorb the impact of a 4,000-lb "moving contoured barrier" delivered at 30 mph from any angle to any point on the periphery of the bus without sustaining damage to the fuel system such that no more than 5 oz of fuel spills during the first 5 min following impact. To meet this requirement, manufacturers of the truck chassis on which Type I school buses are built have surrounded the fuel tanks with structural cages. These cages protect the tanks from blunt impact but may not protect them from punctures that result from concentrated forces delivered to the tank between the structural members of the cage.

In the Carrollton, Kentucky, church bus crash and fire, the fuel tank was apparently punctured by the right-front leaf spring assembly of the bus. The bus was manufactured before April 1, 1977, and did not come under the provisions of FMVSS 301. Had the fuel tank of the bus been surrounded by a structural cage to meet the requirements of FMVSS 301, it is unclear whether it would have been punctured and, therefore, it is unclear whether compliance with FMVSS 301 would have prevented the post-crash fire (Ford Motor Company 1988).[27]

One proposal to enhance the safety of school bus fuel systems is to phase out gasoline-powered school buses and replace them with diesel-powered vehicles. Some school buses are now powered by diesel engines, but decisions to purchase and operate diesel-powered buses have been made principally on economic grounds in the past. However, because of the lower flammability of diesel, some school districts have decided to purchase diesel-powered school buses as a safety measure; for example, since the Carrollton accident, the state of Kentucky has purchased diesel-powered buses exclusively (telephone conversation with Sam Jackson, Kentucky Department of Education, March 8, 1989).

Another proposal to enhance the safety of school bus fuel systems is to relocate the fuel tank to a safer position. Traditionally, school bus fuel tanks have been located on the right side, outboard of the right frame rail of the chassis because this position on the bus is struck least often in real-world crashes. If the tank were moved to a more central location, for example, between the frame rails on the chassis, it would receive greater protection from side impacts to the bus. However, this more central location would require that the filler neck be extended and possibly routed over a frame rail while placing the fuel tank closer to the exhaust system and drive shaft.

No studies or research were found that estimated the safety benefits and economic trade-offs associated with measures to enhance the integrity of school bus fuel systems. Further research on the costs and benefits of enhancing the integrity of fuel systems on school buses is warranted.

FMVSS 302 specifies the flammability properties of materials used in the passenger compartments of school buses (49 CFR 571.302). "The purpose of this standard is to reduce the deaths and injuries to motor vehicle occupants caused by vehicle fires, especially those originating in the interior of the vehicle from sources such as matches or cigarettes." This standard requires that, when ignited, the materials used in school bus interiors (e.g., seat cushions, seat backs, floor coverings) must not spread a flame beyond a prescribed rate. The conditions specified in the standard require that a 4- x 14-in. sample of a material be placed horizontally inside an environmental chamber (of specified characteristics), and when ignited by a 1.5-in. Bunsen burner flame for 15 sec, the material must not burn at a rate of more than 4 in./min.[28]

A National Academy of Sciences study on the test procedure used in FMVSS 302 concluded (NMAB 1979, 88):

> This standard prescribes a test method that tests materials only in a horizontal orientation and is considered by test experts to be almost totally ineffective in providing for fire safety in a real fire situation.

The study recommended that the government (NMAB 1979, 88):

> Develop new standards that will better define the fire performance of combustible materials in vehicles (e.g., standards recognizing that materials oriented vertically may spread flame an order of magnitude faster than the same material tested horizontally).

The study further recommended that the government broaden post-crash fire standards (NMAB 1979, 13) and "develop and implement rapidly regulations concerning allowable parameters for flammability, smoke emission, and toxicity." Finally, with regard to specific materials that should be used inside buses, the study concluded (NMAB 1979, 13):

> The use of presently known flexible polyurethane foam systems in seat cushions is not consistent with overall fire safety; polychloroprene (neoprene) foams currently are the only reasonable substitute cushion materials. Recommendation: Do not use polyurethane foams.

Unfortunately, commercially available polychloroprene (neoprene) does not have the energy-absorption capability of polyurethane. If neoprene were used in place of polyurethane in school bus seat construction, those seats would absorb far less energy than current seats and would not comply with the performance characteristics of FMVSS 222 (School Bus Passenger Seating and Crash Protection) (49 CFR 571.222). School bus accident injuries that result from fire or smoke inhalation might be reduced, but at the expense of additional, and more severe, mechanical trauma injuries.

Although the Urban Mass Transportation Administration (UMTA) requires that padded or cushioned bus seats be constructed of neoprene foam (UMTA 1978, Part II, §2.3.2.4), the Federal Aviation Administration (FAA) allows seat cushioning or padding in airplanes to be constructed from conventional polyurethane foam. However, under FAA regulations, flammable seat cushion foam must be covered by a fire-blocking upholstery that retards the spread of flames, as defined in standardized test procedures (14 CFR 25.853).

At present there is no reasonable alternative to the use of conventional polyurethane foam in the construction of school bus seats. To reduce the fire and smoke hazards posed by polyurethane foam cushions, consideration should be given to upholstering school bus seats with fire-resistant materials, even though such materials are quite expensive.[29] As new, less costly materials are developed with the energy-absorption capability of conventional polyurethane foam, but that are not easily ignited and that do not emit smoke when burned, they should be used in the construction of school bus seats.

Summary

The number of school bus passengers killed and injured in traffic accidents each year is quite low, given the number of students transported and the number of vehicle (school bus) miles traveled. The committee believes that the federal school bus safety standards that went into effect in 1977 (e.g., FMVSS 217, 220, 221, 222, and 301) have been effective in reducing the number of fatalities and injuries to school bus passengers, even though future evaluations of these standards, if based on mass accident data, will probably show little or no effect, at least for severe or fatal injuries. Yet, additional steps might be taken to improve school bus safety.

Several crash-phase safety measures have been proposed to further enhance the safety of school bus passengers; foremost among these are seat belts. Under current federal regulations, seat belts (lap belts) are required at all passenger positions on school buses with GVWRs of 10,000 lb or less. For school buses with GVWRs greater than 10,000 lb (i.e., Type I buses), seat belts are not required. From previous research, the use of seat belts on Type I buses manufactured after 1977 may reduce the likelihood of death of and injury to passengers involved in a school bus crash by up to 20 percent. The experience of several school districts currently operating seat belt–equipped Type I buses indicates that the seat belt use rate for passengers riding in belt-equipped buses is roughly 50 percent.

Two other passenger-restraint systems discussed in this chapter, lap bars and lap and shoulder belts, are still in the research and development stage and have not yet been placed in operational school buses. It is doubtful whether the lap bar will be a viable alternative to the lap belt. The costs and benefits of using lap and shoulder belts in school buses remain to be demonstrated.

School bus passenger injuries and fatalities are most common when the bus is involved in a frontal collision. Because of this the Canadian government has experimented with rear-facing school bus seats to better distribute the load on school bus passengers involved in such collisions. Sled tests conducted on rear-facing seats are encouraging, and preliminary evaluations of rear-facing seats installed in operational school buses indicate that the configuration is generally acceptable to both school bus drivers and passengers. Once the Canadian evaluations are complete, further testing and evaluation in the United States may be warranted.

Available sled test results support the current federal school bus seat spacing standard (≤ 24 in.), but they also indicate that a higher seat back height would provide added protection to school bus passengers. Although real-world data are unavailable, the committee believes that increasing seat back heights from 20 in. (the current standard) to 24 in. would probably reduce the number of school bus fatalities and injuries.

Although no studies have estimated the added risk quantitatively, permitting students to stand in the aisles of school buses is clearly inconsistent with occupant protection requirements that depend on passengers' being seated. Several states have enacted laws that prohibit school bus operators from allowing passengers to stand in school bus aisles (NSBTA, 1984, 9).

The increased use of reflective materials on the exterior of school buses could improve nighttime conspicuity of school buses. Further research is needed to estimate the effectiveness of such materials at reducing school bus accidents.

Post-crash protective measures considered include emergency exit requirements and measures aimed at reducing the likelihood or consequences of post-crash fires. Current standards require only one emergency exit on a school bus regardless of passenger capacity; on buses with left-side emergency exits, manufacturers are permitted to install a seat obstructing the path to the door. No studies were found that attempted to measure the consequences of these policies or the benefits of increasing the number of emergency exits or prohibiting seats in front of emergency exits.

Post-crash fires are very rare, and as a result little research has been done to estimate the safety benefits of further improvements to school bus fuel systems or reducing the flammability of school bus interior materials, particularly seating materials. In the aftermath of the Carrollton, Kentucky, church bus accident, however, further research is recommended. Regarding seating materials, which must have minimum energy-absorbing properties as well as fire resistance, the committee believes that at present there is no reasonable alternative to the use of conventional polyurethane foam in the construction of school buses. However, materials are constantly under development that may offer improved fire resistance, as well as the necessary energy-absorbing properties, at a reasonable cost. Developments in this area should be continually monitored to identify materials for potential school bus use.

Notes

1. School bus seats manufactured for sale in the United States must deform within prescribed limits when forces are applied (in a horizontal direction) to both the front and the rear of the seat back. These forces are applied by a loading bar, a cylinder 6 in. in diameter (hemispherical ends with 3-in. radii) and 4 in. shorter than the width of the seat back being tested. During the test, the loading bar is parallel to the plane of the seat back. The forces applied during the test, as well as the durations of force applications and acceptable minimum and maximum deflections, are specified in the standard.
2. The current definition of seat back height as used in federal regulations is the distance from the top of the seat to the SRP, as defined by the Society of Automotive Engineers in SAE J826. By this definition, the 28-in. height specified in the UCLA study becomes 24 or 25 in. For more details see Figure 4-1.
3. All instrumented dummies used for the three tests conducted in this study conformed to the specifications in 49 CFR 572.
4. Maximum allowable school bus seat spacing in the United States for buses with GVWRs greater than 10,000 lb is 24 in. (49 CFR 571.222).
5. The HIC is a measure of the degree to which a head or head form is assaulted during a collision. HICs greater than 1,000 are generally considered to be unacceptable. Some researchers have questioned whether a single measure such as HIC can adequately represent head injury risk and whether a single threshold value or limit is appropriate (AAAM, 1987). For details on the estimation of HIC values see footnote *a* in Table 4-2.
6. Memorandum to Colleagues Concerned About Child Passenger Safety from Kathleen Weber, and John W. Melvin, Department of Mechanical Engineering and Applied Mechanics, University of Michigan, January 23, 1986.
7. Letter from John D. States to the Honorable Norman J. Levy, Chairman, New York State Senate Committee on Transportation, December 23, 1985.
8. Memorandum from Walter E. Skowronski, Director of Finance and Support Services, Danbury Public Schools, to Anthony L. Singe, Superintendent of Schools for Danbury Public Schools, October 13, 1987, with an attached police accident report and school bus operator report.
9. Memorandum from Walter E. Skowronski to Anthony L. Singe, October 13, 1987, with an attached police accident report and school bus operator report.
10. Memorandum from Walter E. Skowronski to Anthony L. Singe, October 13, 1987, with an attached police accident report and school bus operator report.
11. One of the three children ejected was thrown through the windshield (Case 3, Appendix D). It should be noted that the school bus in this accident was a 1967 Volkswagen van.
12. Letter from W. R. Kyser, Director of Transportation, Katy, Texas, Independent School District, to Susan Bryant, Traffic Safety Section, Texas Department of Highways and Public Transportation, March 9, 1987.
13. Memorandum from N. J. Hatfield to Susan Bryant, April 13, 1987.
14. Estimate by Evans (1986) of the effectiveness of lap belts in reducing fatalities in the rear seats of passenger cars is based on the experience of passengers 16 years old or older. Only a small minority of all school bus passengers are in this age group.

15. Letter from C. Frank Dixon, Jr., Director of Transportation Services, Fairfax County (Virginia) Public Schools to the Transportation Research Board (TRB), October 2, 1987.
16. Letter from Pamela L. Witt, Superintendent of Fairview School District 72 to TRB, October 6, 1987.
17. Letter from Alan P. Austen, Superintendent of Schools, Comsewogue (New York) School District to TRB, October 9, 1987.
18. Letter from Robert M. Brown, Transportation Supervisor, Board of Education, West Orange, New Jersey to TRB, October 14, 1987.
19. Letter from John I. Goss, Director of District Operations for the Marana (Arizona) Unified School District to TRB, October 21, 1987.
20. Letter report by Paul M. Sharp, President, New York Association for Pupil Transportation, March 14, 1988.
21. Includes information provided by Gerald Amabile, Vice President of Safety Research and Manufacturing In.., May 25, 1988.
22. "School Bus Demonstration Project—Rearward Facing Seats with Lap Belts" (Leaflet), Transport Canada, Ottawa, Ontario, Canada.
23. Preamble to FMVSS 222, School Bus Passenger Seating and Crash Protection (Docket 73-3; Notice 5).
24. Technically, the use of retroreflective materials on bus exteriors is a pre-crash, not a post-crash, measure intended to prevent accidents.
25. Requiring school buses to operate with their headlights on during daylight hours might also increase the visibility of school buses. However, by their size and marking, school buses are already conspicuous vehicles, and thus the added safety benefits would probably be quite small. Moreover, by making vehicles that use their headlights during daylight hours more common, such a policy for school buses might diminish the conspicuity of other vehicles, such as motorcycles, that increasingly rely on their headlights to provide added conspicuity during daylight hours.
26. On November 4, 1988, NHTSA announced that it is considering amending FMVSS 217 to require more emergency exits on school buses. "The agency seeks comments on the extent to which such an amendment would help to speed the evacuation of a bus following a crash, as well as on the costs and operational aspects of additional exits, and on any negative effects (such as reductions in structural integrity or seating capacity)." Docket 88-21: Notice 1. *Federal Register*, Vol. 53, No. 214, pp. 44623–44627.
27. NTSB is currently investigating the Carrollton church bus crash. A final report of the findings has not yet been issued.
28. On November 4, 1988, NHTSA announced that it is considering upgrading FMVSS 302 as it applies to school buses with GVWRs greater than 10,000 lb. The agency ". . . requests comments on possible proposals relating to matters such as self-extinguishing seating materials [i.e., materials which, after being ignited, cease to burn when the source of ignition is removed], toxicity of fumes given off by burning or smoldering seating materials, smoke from burning or smoldering materials and upgraded test procedures." Docket 88-22: Notice 1. *Federal Register*, Vol. 53, No. 214, pp. 44627–44632.
29. At least one school bus manufacturer now offers fire-resistant upholstery (Kevlar) as an option on its buses. The added cost of Kevlar upholstery is $47.54 per seat, or $1,045.88 for a 66-passenger school bus (letter from Malcolm B. Mathieson, Vice President for Engineering, Thomas Built Buses, Inc. to TRB, October 19, 1988).

References

ABBREVIATIONS

AAAM	Association for Advancement of Automotive Medicine
NHTSA	National Highway Traffic Safety Administration
NMAB	National Materials Advisory Board
NSBTA	National School Bus Transportation Association
NTSB	National Transportation Safety Board
UMTA	Urban Mass Transportation Administration

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5 Measures To Prevent School Bus and Pedestrian Accidents

EACH YEAR IN THE United States 45 pedestrians, on average, are killed in school bus–related accidents; 38 of these pedestrians are children most often killed boarding or leaving buses in school bus loading zones. In addition to the children killed in loading zones (KDOT 1986), another 800 are injured.

A variety of measures that are intended to reduce the frequency of school bus and pedestrian accidents are reviewed in the three sections in this chapter. The first section discusses behavioral measures to reduce the number of pedestrian accidents, including selection and training of school bus drivers, training of school bus passengers, and use of adult monitors on board school buses. The second section discusses physical measures to prevent pedestrian accidents such as signals, communications equipment, mirrors and sensors, and barriers. The final section discusses the effects of the location of school bus routes and stops on safety.

Behavioral Measures To Prevent Pedestrian Accidents

Attempts to reduce the number of school bus and pedestrian accidents through behavior modification fall into three categories: (a) selection and training of school bus drivers, (b) pupil instruction, and (c) pupil supervision.

Selection and Training of School Bus Drivers

In 1969 the National Highway Traffic Administration (NHTSA) initiated a study on the selection and training of school bus drivers. "The objective of the study was to establish a set of selection requirements and training objectives that would enable pupil transportation administrators to assure, within the resources available, that newly employed drivers had the required qualifications" (McKnight et al. 1971, iii). The study includes a description of specific background and psychological and physical characteristics that should be reviewed when school bus drivers are selected and recommends that each newly employed driver receive at least 6 to 12 hr of instruction (14 to 25 hr in larger pupil transportation systems). The topics that should be covered in driver training include (McKnight et al. 1971, iv):

- Pupil transportation systems and driver duties,
- School bus operating procedures,
- General traffic and school bus laws and regulations,
- Responsibilities to pupils,
- Preventive maintenance,
- Administrative requirements, and
- Emergency and accident-related procedures.

As a follow-on to this study on the selection and training of school bus drivers, NHTSA developed two courses: (a) a core course that covers the skills needed by all school bus drivers and (b) an advanced course that covers skills that might be needed under certain circumstances. The course materials were published in five reports: a course guide (NHTSA 1974a), two trainee study guides (NHTSA 1974b, c), and two instructor's guides (NHTSA 1974d, e). The core course contains five units of instruction: introduction to school bus driver role and responsibility, passenger control, accidents and emergencies, bus maintenance and inspection, and driving fundamentals (NHTSA 1974d, 1). The advanced course contains eight units of instruction: emergency driving techniques, first aid, field trips, transporting exceptional children, detecting hazards, controlling the position of the bus, driving under special conditions, and preventive maintenance (NHTSA 1974d, 1).

In a series of workshops in the fall of 1974, the school bus driver curriculum was presented to 78 enrollees representing 47 states. Each workshop was 30 hr and extended over a 5-day period. The purpose of the workshops was not to train individual school bus drivers, but "to (1) provide potential instructors with a detailed explanation of the design, development and use of the NHTSA school bus driver curriculum packages, and (2) train potential instructors in teaching methodology pertinent to the curriculum package" (Cleven and Fucigna 1975).

NHTSA has been joined by a number of other organizations and associations in its effort to develop procedures and programs to better select and train school bus drivers. Among the more recent groups are the 1985 National School Bus Standards Conference (NSBSC 1985), the AAA Foundation for Traffic Safety (Farmer 1985), and the Association of School Business Officials International (Farmer 1987).

In spite of the efforts of NHTSA and other concerned organizations, the state requirements for school bus driver selection, licensure, and training are highly variable (Table 5-1). Some states require neither a special road test nor training for school bus drivers before they transport children. As states comply with recently issued federal commercial driver's license requirements (by April 1, 1992), however, licensing of school bus drivers will become generally more stringent. The requirements for a commercial driver's license will apply to most school bus drivers; the driver of any bus with a gross vehicle weight rating (GVWR) greater than 26,000 lb or a passenger capacity greater than 16, unless used for strictly private purposes, will be required to have a commercial driver's license endorsed for the size of bus operated. Although specific license testing may still vary from state to state, it must include a road test in a bus and a written test that contains questions on operation of large vehicles generally and specific questions on bus operations (49 CFR Part 383).

Despite the interest in training programs and their obvious link to school bus safety, no studies have been found that reliably estimate the effectiveness of school bus driver training in reducing accidents.

Nevertheless, the committee believes that school bus driver training programs developed by NHTSA and other organizations have the potential to reduce school bus accidents.

Pupil Instruction

In addition to development of better procedures for selecting and training school bus drivers, a number of organizations have advocated increased and improved instruction for students who ride school buses.

For example, the 1985 National School Bus Standards Conference recommended that "since most pupils ride to and from school or [to and from] activity trips, it is essential that all be taught safe riding and pedestrian practices. Instructional programs appropriate for each grade level and for the needs of each group of youngsters should be developed" (NSBSC 1985, 97). Among the specific topics that children should be taught, according to NSBSC, are

TABLE 5-1 SCHOOL BUS DRIVER REQUIREMENTS IN 41 OF THE 50 STATES

State	License	Training
Alabama	Regular license; special license annually; written and road tests; TB exam every 3 yr.	12 hr state preservice instruction; 6 hr in-service annually.
Alaska	Regular license for at least 1 yr; annual DPS permit; written and road tests; annual physical exam; minimum age 19; good driving record.	No state requirements; 0 to 40 hr local training; proposed 1987 implementation of 40 hr preservice and 10 hr in-service training.
Arizona	Chauffeur's license; annual physical exam; clean driving record; 65 maximum age; written and road tests; fingerprint check.	12 hr state preservice instruction; 8 hr in-service every 2 years; 8 hr first aid course.
Arkansas	Regular license; 2 yr bus driver certificate; physical exam every 2 yr; written and road tests; clean driving record within 5 yr.	State-prescribed preservice and in-service training taught locally.
California	Regular license; bus driver certificate every 4 hr; physical exam every 2 yr; minimum age 18; over 65, annual physical exam; written and road tests for certificate renewal.	40 hr preservice training (20 hr classroom, 20 hr road) by state-certified instructors; 10 hr in-service annually; first aid exam.
Connecticut	Regular license; age 18 to 70; annual physical exam; annual road and written tests, fingerprinting and no criminal record.	7 hr preservice and 3 hr in-service annually by state-certified instructors.
Florida	Chauffeur's license; annual bus driver license; physical exam; written and road tests at age 65; 6-month license.	Administrative rule in 1986 will require 40 hr preservice and 8 hr in-service annually.
Georgia	Regular license; Class 3 license; annual physical exam; 65 maximum age.	6 hr preservice classroom instruction; 6 hr road training without pupils; 6 hr road training with pupils; state requirements developed locally.
Idaho	Chauffeur's license; minimum age 18; physical exam; driving test.	10 hr state preservice instruction; 8 hr in-service annually.
Illinois	Regular license; annual permit; minimum age 21; annual physical exam; written and road tests; no criminal record within 5 yr; no more than two traffic violations within 1 yr.	Variable local classroom training before superintendent issues school bus driver permit.

TABLE 5-1 *continued*

State	License	Training
Indiana	Chauffeur's license; state bus driver certificate.	20 hr state preservice classroom instruction; additional local training as desired.
Iowa	Chauffeur's license; bus driver permit; annual physical exam; age 18 to 69	Voluntary 18 hr preservice classroom instruction provided locally.
Louisiana	Chauffeur's license; bus driver certificate; road and written tests; driver and criminal record checks; physical and psychological exams; age 21 to 55.	40 hr state preservice (30 hr classroom, 10 hr road); 8 hr in-service annually.
Maine	Class 2 license; annual permit; minimum age 18; road test; physical exam.	No state requirement; local training requirements.
Massachusetts	Regular license for 3 yr; minimum age 18; annual physical exam.	State preservice and in-service training annually.
Michigan	Chauffeur's license; Class 3 endorsement; annual road test; written test; annual physical exam; minimum age 18; good driving record (less than 7 points).	State-approved preservice training; local in-service instruction.
Minnesota	Regular license with bus endorsement; road and written tests; minimum age 18; physical exam every 2 yr; criminal and driving record checks; renewal every 4 yr.	No state requirement; local training requirements very.
Mississippi	Regular license with annual bus endorsement; age 17 to 70; physical exam.	16 hr preservice training developed locally and taught by state-approved instructors.
Missouri	Chauffeur's license; minimum age 21; written and road tests.	Voluntary state training may be required by local district; state-certified instructors.
Montana	Chauffeur's license; 5 yr driving experience; physical exam; first aid certificate.	Voluntary state training program used by about one-half of the school districts.
Nebraska	Regular license; bus driver permit; annual physical exam; age 18 to 65; annual written and road tests; good driving record check.	10 hr state-approved training.
Nevada	Class 2 license every 4 yr; physical exam every 2 yr; annual written exam.	20 hr state preservice (10 hr classroom, 10 hr on road) and annual refresher course.

TABLE 5-1 *continued*

State	License	Training
New Hampshire	Regular license; bus driver certificate; minimum age 18; English-speaking written test; criminal and driving record check.	State-approved training; 8 hr preservice road and classroom instruction; 6 hr in-service annually.
New Jersey	Regular license; certificate every 2 yr; 3 yr driving experience; minimum age 18; physical exam; written and road tests; driving record check.	No state requirement; state assistance to local districts offering training.
New York	Regular license; physical exam every 2 yr; no driving record (3 yr) or criminal record (5 yr); written and road tests every 2 yr; 3 yr employment check; annual driving record check; age 21 to 65.	2 hr state preservice classroom instruction; 2 hr twice a year in-service training; additional local training optional.
Ohio	Chauffeur's license; annual bus certificate; minimum age 18; physical exam; written and road tests; annual driving record check.	20 hr state preservice (12 hr classroom, 8 hr on road); 1 hr annual in-service training; some local districts require more.
Oklahoma	Chauffeur's license; 5 yr certificate; annual physical exam; minimum age 18; clear driving record for 3 yr; at age 64, 1-yr certificate.	5-day (25 hr) state preservice workshop; local in-service training each semester.
Oregon	Chauffeur's license; age 18 to 70; physical exam; road test; criminal and driving record checks; first aid certificate.	20 hr state preservice training (10 hr classroom, 10 hr road); refresher course every 4 yr.
Pennsylvania	Regular license; bus license; annual physical exam; minimum age 18; road and written tests.	State-approved local preservice (7 hr classroom, 3 hr road); 10 hr in-service every 4 yr.
Rhode Island	Chauffeur's license; 1 yr driving experience; age 18 to 65; annual physical exam; driving record checks; character references.	State-approved preservice training (9 hr classroom, 1 hr road); 3 hr in-service annually for renewal.
South Carolina	Regular license; bus certificate; age 16 to 65; no accidents or violations; initial physical exam; written test.	State training.
South Dakota	Regular license; bus license; bus certificate every 3 yr; annual physical exam; minimum age 18; road and written tests.	No state requirement; about one-half of drivers attend annual seminars sponsored under federal funding.

TABLE 5-1 *continued*

State	License	Training
Tennessee	Special chauffeur's license with endorsement; 5 yr driving experience; annual physical exam; over 55, semiannual physical.	4 hr state in-service classroom instruction; districts may require more training.
Texas	Chauffeur's license; 3-yr bus certificate; annual physical exam; minimum age 18.	20 hr state preservice classroom training (plus road experience); 8 hr refresher training.
Utah	Regular license, S1 license; written and road tests.	24 hr state course; 8 hr in-service training locally; 8 hr first aid training every 4 yr.
Vermont	Regular license; minimum age 18; written and road tests every 4 yr; physical exam.	8 hr state preservice classroom training; 8 hr in-service training every 4 yr; local district may require more training.
Virginia	Regular license; written and road tests; physical exam; two character references; age 17 to 70; driving and criminal record checks.	Local classroom and road training by state-educated instructors; 4 hr in-service each yr; districts may require first aid course.
Washington	Regular license with 1 to 2 yr driving experience; bus certificate every 4 yr; annual physical exam; minimum age 18; first aid certificate every 3 yr; criminal and driving record checks.	Local training by state-educated instructors; generally preservice and in-service training.
West Virginia	Chauffeur's license; bus certificate; age 18 to 70; 1 yr driving experience; annual physical exam; written test; driving record check; first aid certificate.	30 hr state preservice classroom instruction; district may require road training; 16 hr in-service training.
Wisconsin	Regular license, no criminal record for 5 yr; written and road tests; physical exam.	No state requirement; local district may require attendance at annual state workshops.
Wyoming	Class S license; minimum age 18; written and special road tests; annual physical exam.	No state requirement; many local districts have training programs.

NOTE: Survey of states' school bus driver requirements conducted by G. Keiser, Alaska State Legislature Research Agency, in 1985. Data for Tennessee updated as of January 1989.
SOURCE: National School Bus Report 1986, pp. 16–17.

- Safe walking practices to and from bus stops,
- How and where to wait safely for the bus, and
- How to board and leave the bus.

Figures 5-1 and 5-2 show the procedures recommended by NSBSC for boarding and leaving school buses (NSBSC 1985, 99–100).

WHEN BOARDING YOUR BUS:

Here's How to Cross the Road

SAFELY

FOLLOW THE 10-FOOT RULE

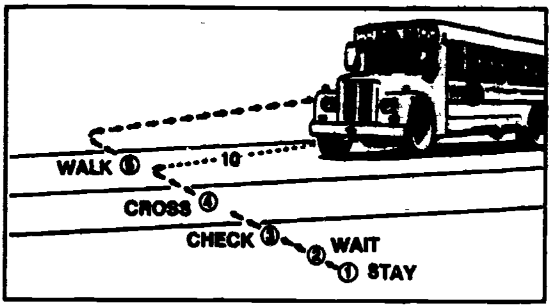
STAY — on your side of the road--far away from the traffic

WAIT — for the bus to stop and for your driver's signal to cross

CHECK — traffic both ways--then check again

CROSS — walk directly across checking traffic both ways

WALK — approximately 10 feet ahead of the bumper and board bus quickly



REMEMBER
- Stay on your side of the road until your driver signals you to cross
- Check and recheck for traffic
- Follow the 10-foot rule
- Board bus quickly--go directly to your seat

Drivers SHOULD stop...But THEY MAY NOT!

FIGURE 5-1 Procedures for safely boarding a school bus.

WHEN LEAVING YOUR BUS:

Here's How to Cross the Road

SAFELY

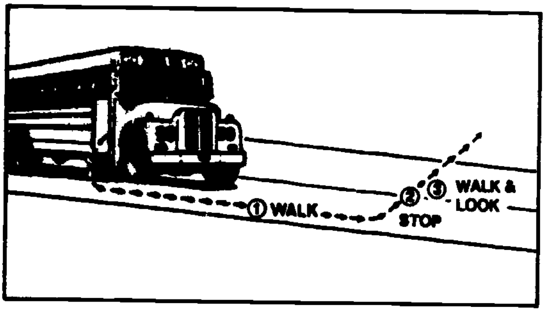
WALK — along the side of the road until you can see your driver

STOP — wait for the signal to cross

WALK & LOOK — for traffic both ways

— if you see a vehicle that has not stopped, go back to the bus immediately

— if all vehicles have stopped, cross the road quickly



Crossing the Highway is DANGEROUS

REMEMBER
- WALK
- STOP
- WALK & LOOK

Drivers SHOULD stop...But THEY MAY NOT!

FIGURE 5-2 Procedures for safely leaving a school bus.

In 1977 NHTSA initiated a project (PEDSAFE) to develop a pedestrian safety curriculum for rural and suburban children in grades K through 12. For the elementary grades, the PEDSAFE program is taught in a series of 10 presentations per year that require about 6 hr of class time. Among the 10 types of pedestrian accidents addressed by PEDSAFE is the school-bus–related pedestrian accident (Ducker and Chiplock 1981).

The portion of the curriculum that addresses school bus and pedestrian accidents is limited to grades K through 6 and is taught both in the classroom and on the bus. Classroom instruction involves the use of movies (Willy Whistle) and other audiovisual aids, games, and prizes. Brochures are sent to parents to enlist their help in promoting pedestrian safety and asking them to practice crossing streets at bus stops with their children. The on-bus instruction is provided by the school bus driver and is conducted in three sessions, ideally, within 2 weeks (Dueker and Chiplock 1981).

To evaluate the PEDSAFE program and its effect on the behavior of children as they board and leave school buses, the program was field tested in three rural or suburban school systems in Western Pennsylvania. Two comparable school systems served as a control group. From observations of children as they boarded and left stopped school buses in the school systems that received PEDSAFE instruction versus those of the children in the control group, the evaluators concluded that children who received PEDSAFE training behaved more safely (Dueker and Chiplock 1981).

Although both the NSBSC and NHTSA have urged states to instruct children in safety procedures for boarding and leaving school buses and the proper behavior on board school buses, much more work is apparently needed (Pavlinski et al. 1982, 2–3):

> [Among the states] ... [t]here is a difference in the amount, quality, and content of pupil instruction related to safe riding practices; emergency evacuation drills; and, pedestrian safety related to "going to" and "coming from" school buses. Although HSPS 17, Pupil Transportation Safety, calls for semi-annual training for school bus riders, most States are doing very little to train pupil passengers to be safe in and around the school bus.

Although there are no studies available that measure the effectiveness of behavior-based, pedestrian education programs in reducing school bus and pedestrian accidents, a number of studies have evaluated other, similar pedestrian safety programs for children and reported mixed results depending on factors such as the age of the children involved, training techniques employed, repetition of the training techniques, and the pedestrian environment (Guyer et al. 1985). Recent evaluations of education programs developed for NHTSA, which are aimed at reducing midblock dart-and-dash pedestrian accidents for 3- to 8-year-old children (Preusser and Blomberg 1984) and other types of pedestrian accidents for 9- to 12-year-old children (Preusser and Lund 1988), report accident reductions of up to 20 to 30 percent over a 2-year period following establishment of the program.

Pupil Supervision

To many the belief that student behavior can be modified through classroom instruction is little more than wishful thinking. Instead they advocate putting monitors on school buses to ensure appropriate behavior. Monitors could ensure that students remained in their seats with heads and arms inside the bus, and they could reduce driver distractions through better control of the students. On buses equipped with seat belts, they could ensure that children are buckled in their seats and that belts are correctly worn. Monitors could also be used as crossing guards to accompany children (particularly younger children) across streets when they board or leave school buses. This last function—escorting children across streets when they board or leave the bus—has the greatest potential for saving lives and reducing injuries.

It is generally agreed that the use of school bus monitors would enhance school bus safety; however, opponents of the program argue that staffing school buses with monitors nationwide would be impractical. Even if 390,000 responsible adults could be found to serve as school bus monitors, the cost for their services would be prohibitive, beyond the resources of most school districts.

As an alternative to the use of school bus monitors for escorting children across streets, the state of California requires that the bus driver provide this service. Under California law, students in grades K through 8 must be escorted by the driver when crossing a road after leaving a school bus (Title 5, California Administrative Code 1101): "The driver, at school bus stops described herein, shall escort pupils attending elementary school across the street or highway, and shall, if necessary, escort other pupils across the street or highway." To comply with the law, the school bus driver must turn off the engine, turn on the flashing lights, take the key out of the ignition, and accompany the child across the road. When students leaving the bus do not need to cross the street, the driver must stop the bus without turning on the flashing lights; other vehicles are not required to stop.

Some operational objections have been raised about the California program—longer delays to other traffic at bus stops where children must be escorted and leaving children unattended on a parked school bus. The longer delays to other traffic at stops where children are escorted are offset to some extent because other traffic is not required to stop where children leaving the bus do not need to cross the street. Although leaving children unattended on a parked bus creates the potential for mishap, California reports few problems with the practice.[1]

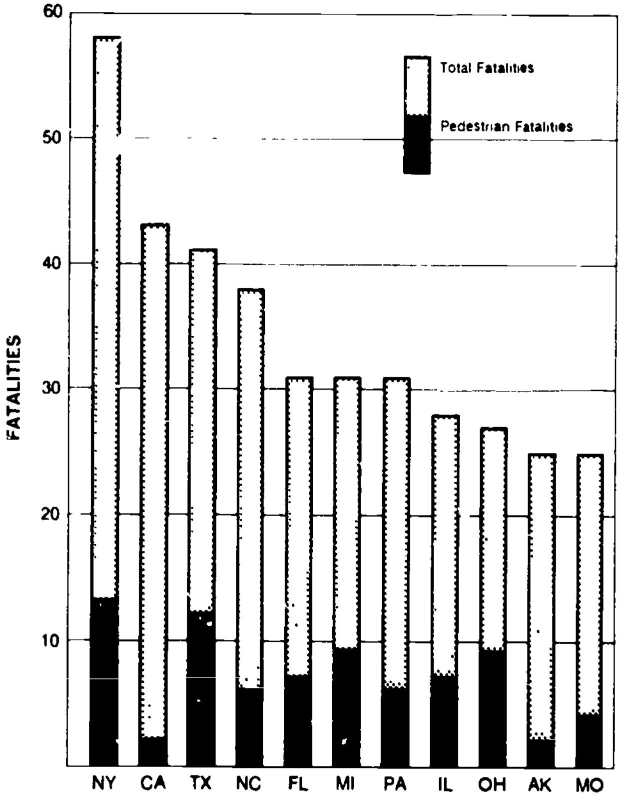


FIGURE 5-3 School bus accident fatalities (total fatalities and pedestrian fatalities) for 11 states (FARS 1982–1986).

With regard to safety effectiveness, the data in Figure 5-3 suggest, but do not prove, that the law may be having a beneficial, perhaps substantial, effect.[2] Between 1982 and 1985, 43 people were killed in school bus–related accidents in California; 2 were pedestrians under 20 years old. During the same period, 41 people were killed in school bus–related accidents in Texas; 12 were pedestrians under 20 years old. Indeed, of the 11 states in which 25 or more fatalities resulted from school bus–related accidents between 1982 and 1985, only Arkansas had as few student pedestrian fatalities as California.

Physical Measures To Prevent Pedestrian Accidents

A number of devices have been marketed to prevent school bus–related pedestrian accidents. These devices fall into two categories: (a) devices to prevent pedestrians from being struck by other vehicles, and (b) devices to prevent pedestrians from being struck by school buses. Both warning signals and communications equipment have been used to prevent other vehicles from striking pedestrians, and various types of sensors and barriers have been used to prevent school buses from striking pedestrians.

Pedestrians Struck by Other Vehicles

Of the 38 children killed in school bus loading zones each year, one-third are killed by vehicles other than school buses. Typically these other vehicles are automobiles or trucks that have illegally passed a school bus that has stopped to load or unload passengers. The following narratives provide some insight into how these accidents occur (KDOT 1986, 17–21):

- An 8-year-old male student departed a school bus, walked on the shoulder of the road behind the bus, and crossed between stopped cars. As the bus started in motion, an oncoming vehicle struck and killed the student.
- The school bus stopped and discharged a 7-year-old student in a downtown area. The student crossed in front of the school bus, which was operating flashing lights. Another vehicle disregarded the lights and passed the school bus from the rear, striking the student.
- The school bus stopped to unload two students. Immediately after the students had exited the bus, a milk truck struck the bus in the rear, pushing it 150 ft down the highway. The milk truck then skidded over an 8-year-old student.
- The school bus was stopped with flashers operating and a 6-year-old student proceeded across the street to catch the bus. A passing car did not stop and struck the student.
- A 6-year-old student was hit by a motorcycle while crossing the road to catch a stopped school bus.

One-third (12 of 38) of all children *killed* and two-thirds (525 of 808) of all children injured in school bus and pedestrian accidents are struck by other vehicles.

Signals

In order to prevent vehicles from illegally passing school buses, various signals have been devised to alert motorists that the bus has stopped (or is stopping) and that they are also obliged to stop, as required by law in most states. Minimum standards now require eight warning and loading lights on all school buses: two flashing red lights and two flashing amber lights on the front and the rear of all school buses (Figure 5-4). The amber lights warn that the bus is preparing to stop; the red lights indicate that the bus has stopped and is loading or unloading students. In addition to these eight lights, school buses also have brake/hazard lights and turn indicators (NSBSC 1985, 21–22).[3]

At the 1985 National School Bus Standards Conference, "stop signal arms" (Figure 5-5) were recommended as standard equipment on school buses (NSBSC 1985, 27):

> There shall be a stop signal arm installed on the left outside of the body. Arm shall be of an octagonal shape with white letters and border and a red background. Flashing lamps in stop arms shall be connected to the alternately red flashing signal lamp circuits.

Stop signal arms are now required equipment in 28 states and are optional[4] in 6 others. Sixteen states do not require stop signal arms on school buses.

For school districts in which buses routinely operate under adverse conditions (e.g., fog and darkness), NSBSC has recommended minimum standards for installing optional strobe lights (NSBSC 1985, 22).

Few field evaluations of school bus signals have been conducted; however, in a study published in 1983 Hale et al. evaluated the effectiveness of the eight-light system used alone and in conjunction with stop signal arms. Conducted in Columbus, Ohio, the study was based on passing violations reported to police by school bus drivers during school years 1979–1980, 1980–1981, and 1981–1982. During this period, 157 school buses operated in Columbus with the older four-light system (four flashing red stop lights). Another 301 school buses operated with the eight-light system (four flashing red stop lights and four flashing amber warning lights). Eighty-eight of the 301 buses were equipped with stop signal arms (Table 5-2). Little difference is seen between reported passing violations for school buses equipped with four-light systems and those for eight-light systems (without stop signal arms). However, buses that were equipped with eight-light systems and stop signal arms recorded almost 40 percent fewer passing violations (Hale et al. 1983, A-13).

Brackett et al. (1984, *School Bus Safety*) attempted to evaluate the effectiveness of stop signal arms in reducing the number of vehicles illegally passing stopped school buses. They observed the behavior of motorists approaching stopped school buses that were equipped with stop signal arms and buses without them (Table 5-3). Buses operating on 19 routes were observed for approximately 3 weeks (267 bus days) before and 3 weeks (251.5 bus days) after they were equipped with stop signal arms. The

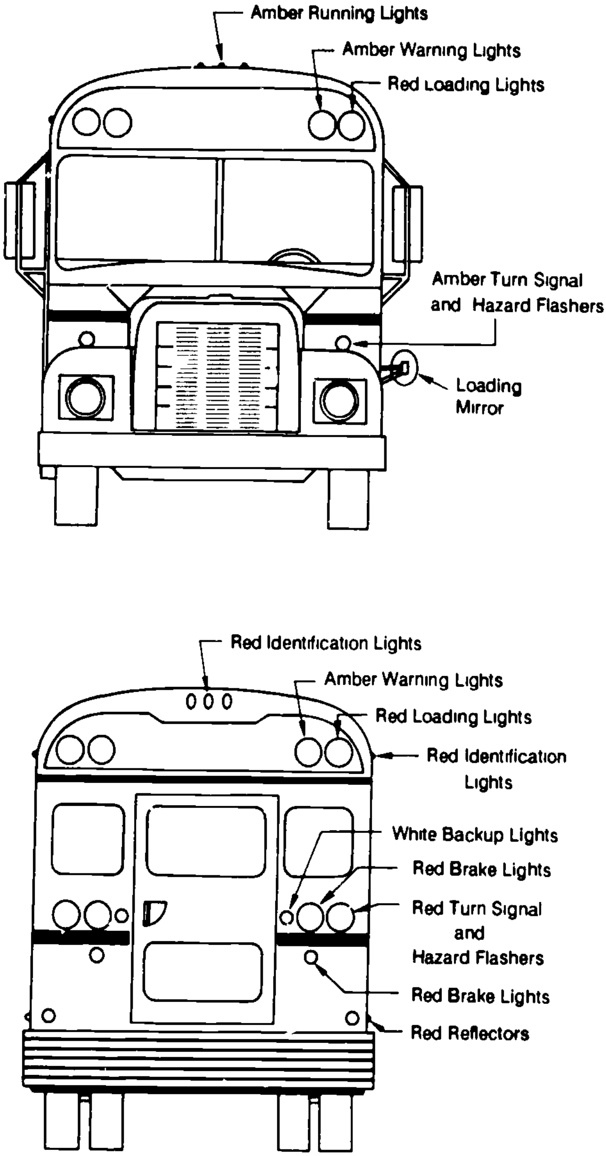


FIGURE 5-4 School bus lighting configurations (Brackett et al. 1984).

FIGURE 5-5 School bus equipped with stop control arm.

TABLE 5-2 SCHOOL BUS PASSING VIOLATIONS ASSOCIATED WITH THREE SIGNAL SYSTEMS (Hale et al. 1983, A-13)

Signal System	No. of School Buses	No. of Passing Violations	No. of Average Violations per Bus
Four-light	157	157	1.00
Eight-light	213	217	1.02
Eight-light plus stop signal arms	88	55	0.63
	458	429	

NOTE: Data are from school years 1979–1980, 1980–1981, and 1981–1982.

researchers found that before the installation of stop signal arms, school buses were passed illegally at 964 (17.7 percent) of 5,436 stops at which traffic was present. After the arms were installed on the buses serving these routes, passing violations were recorded at only 471 (9.2 percent) of 5,124 stops at which traffic was present, a reduction of 48 percent. Six routes (control group)

TABLE 5-3 EVALUATION OF STOP SIGNAL ARMS (Brackett et al. 1984, *School Bus Safety*, 12)

Experiment Group	Treatment	Total Stops with Traffic	Stops with at Least One Illegal Pass	Percent with at Least One Illegal Pass
Test[a]				
Before	No stop arms	5,436	964	17.7
After	Stop arms	5,124	471	9.2
Control[b]				
Before	No stop arms	1,024	129	12.6
After	No stop arms	1,309	183	14.0

NOTE: Bus days observed in test group of 19 routes = 267.0 with no stop arms and 251.5 with stop arms; bus days observed in control group of 6 routes = 78.0 with no stop arms and 92.5 with stop arms.

[a]The reduction in the number of stops at which a bus was illegally passed (17.7 percent versus 9.2 percent) was statistically significant ($\chi^2_{(1)} = 163.88$; $pr < .001$).

[b]The increase in the number of stops at which a bus was illegally passed (12.6 percent versus 14.0 percent) was not statistically significant ($\chi^2_{(1)} = 0.95$; $pr > .30$).

served by buses that were not equipped with stop signal arms during the experiment showed no reduction in passing violations.

Brackett et al. (1984, *School Bus Safety*) concluded that stop signal arms are effective in reducing illegal passing, but they cautioned that the magnitude of the effect, a 48 percent reduction in the number of stops where illegal passing occurred, may be exaggerated as a result of "regression-to-the-mean." At the start of the experiment, illegal passing was higher for the treatment group than for the control group. The researchers reason that some reduction in passing violations would have occurred on the treatment routes even without the installation of stop signal arms on the buses serving these routes. Accounting for regression-to-the-mean, they estimated that passing violations can be reduced about 30 percent through the use of stop signal arms. It is unclear how this figure translates into reduced pedestrian accidents.

In an attempt to improve the effectiveness of stop signal arms, the Metropolitan Public Schools in Nashville, Tennessee, modified two of its school buses equipped with stop signal arms by adding red strobe lights. These two buses and two other buses equipped with standard stop signal arms were then operated for 4 weeks on heavily traveled main arteries in Nashville. Records were kept of the number of times that the four buses were passed when their stop arms were extended. The standard buses were illegally passed 109 times (i.e., each bus was illegally passed 2.7 times per day); the buses modified with strobe lights were illegally passed 8 times (i.e., each bus was illegally passed 0.2 time per day).[5] (The results of this 4-week study are given in Table 5-4.)

TABLE 5-4 EFFECTIVENESS OF STOP SIGNAL ARMS MODIFIED WITH STROBE LIGHTS

	No. of Vehicles Passing School Bus Illegally[a]
Buses with standard stop signal arms	
Bus 1	68
Bus 2	41
Total	109
Buses with stop signal arms and strobe lights	
Bus 3	7
Bus 4	1
Total	8

NOTE: Data provided by Carlisle Beasley, Director of Transportation, Metropolitan Public Schools, Nashville, Tennessee.

[a]Based on observations made during 4 weeks of service. Each bus operated on a different route in September–October 1983.

The data in Table 5-4 are confounded by the fact that the four buses traveled different routes. Had the buses rotated routes during the 4-week study, the effect of route on illegal passing of stopped school buses could have been factored out. Because the routes were not rotated, some (and possibly all) of the apparent reduction in passing violations attributed to strobe lights may be due to differences in routes, not differences in stop arm designs.

Existing studies of the effectiveness of stop signal arms in reducing illegal passing of stopped school buses are impressive. Although it is difficult to quantify the safety effect by these studies, the committee believes that the use of stop signal arms will reduce the number of pedestrians struck by other vehicles in school bus loading zones. If the standard flashing red lights on the stop arm were replaced with red strobe lights, the effectiveness of stop arms might be further enhanced.

Communications Equipment

The purpose of warning lights, loading lights, stop signal arms, and strobe lights on school buses is to alert motorists that the bus is stopping or has stopped. If motorists do not understand these signals (and their obligation to stop), or do not intend to stop, the signals are of limited benefit.

In a second study conducted at the Texas Transportation Institute (TTI), Brackett et al. (1984, *Preliminary Study*) again recorded the frequency with which stopped school buses were illegally passed. Field observations indicated that on a typical school day each bus operating in the Houston Independent School District was illegally passed an average of 8.33 times. In San Antonio, school buses were illegally passed 4.65 times. Although these passing violations are a relatively small percentage of all stops made by school buses, each one represents an opportunity for a pedestrian accident.

Results of a driver survey conducted during the course of the TTI study by Brackett et al. revealed considerable misunderstanding among motorists about the appropriate (legal) behavior toward stopped or stopping school buses in Texas (Brackett et al. 1984, *Preliminary Study*, 11):

> 1. There is no requirement for vehicles to stop for yellow warning lights or hazard lights, yet nearly half (48%) of the subjects surveyed said that they would stop for the yellow warning lights and another 31 percent for the hazard lights only. These are errors of caution, i.e., stopping when it is unnecessary. These high error percentages can be practically explained by the tendency of subjects to be more conservative under a survey situation. However, it also indicates that a significant portion of the drivers do not fully understand the meanings of various signal configurations.
> 2. There is also no requirement for traffic in the opposing lanes of a divided highway to stop even though the school bus is displaying the red loading lights. Nearly 95 percent of the subjects shown this configuration stated that they would stop. Again, these are errors of caution. It is evident from the data that the majority of drivers are not aware of the state law regarding stopping for school buses on multi-lane facilities.
> 3. With only red loading lights, 6.2 percent of the drivers indicated that they would proceed without stopping. These are termed errors of recklessness, i.e., not stopping when necessary. When the red loading and hazard lights are used simultaneously, the error percentage actually increased to over 10 percent. *This confirms the earlier observation that many drivers are confused about the meanings of various signal configurations.* [Emphasis added.]

Because some motorists may not understand when to stop for a stopped school bus, or do not intend to stop, other methods of ensuring the safety of children as they cross streets to board a bus or when they cross streets after leaving a bus have been adopted. All of these methods involve communication between the bus driver and the student. In some states (e.g., New York) children are not permitted to cross the street in front of a school bus until signaled by the driver. The signal used varies among school districts; in some districts it is a gesture by the driver or a beep of the horn. One school district has installed small white lights on the front of its buses. When it is safe to cross the street the driver turns on the lights, and the student proceeds across the street.[6]

In other school districts, buses have been equipped with external loud speaker systems (Figure 5-6) that enable the driver to communicate with students outside of the bus and verbally inform them when it is safe to cross the street. It has been argued that this system is more flexible and, hence, safer than other nonverbal forms of communication between the driver and student. A driver's verbal instructions to even the youngest of children are less ambiguous than a hand signal, the beep of a horn, or the flashing of a light. Furthermore, with verbal communication the driver's instructions can be altered (or reversed) right up to the time the student crosses the street.

To date, external loud speaker systems have been installed on several thousand school buses. Various school districts have provided testimonials in support of this device, but no formal evaluation of the effectiveness of external loud speaker systems in reducing the number of pedestrian accidents or improving pedestrian behavior has been undertaken. Nevertheless, the committee believes that properly trained drivers using loud speakers would reduce the number of pedestrian accidents.

FIGURE 5-6 External loud speaker systems aid children in crossing a street or highway when they board or leave a school bus.

Pedestrians Struck by School Buses

Two-thirds of all children killed in school bus and pedestrian accidents are struck by school buses or vehicles used as school buses (Table 3-25, Chapter 3). Of those killed (about 26 in an average year), two-thirds are struck by the front of the bus and one-third by the rear of the bus, usually the rear wheels. The following narratives describe how such accidents occur (KDOT 1986, 17–21):

- An elementary student was struck and killed by a school bus on a foggy morning. The child was late and was hit as she attempted to cross in front of the moving bus.
- A 6-year-old female student departed the bus and crossed the roadway. She came back across the road to pick up papers and was not seen by the driver. The rear wheels of the bus ran over the student.
- Four students exited the school bus and started to cross the highway. The bus driver thought all the students had cleared the road and proceeded to move forward, striking a 6-year-old female student with both front and rear wheels.
- A kindergarten child was killed in the unloading area at the school. The school bus made a right turn after unloading; the child was pushed or fell under the rear wheels.
- A student was late for the bus. The bus had pulled away from the stop and was proceeding on its run. The student chased the bus. [Unaware that the student was chasing the bus,] the driver stopped at a sign prior to making a right hand turn. As the bus began to turn right, the student caught up with the bus and apparently slid in front of the right rear duals.

In addition to the children killed in loading zones when struck by school buses, it is estimated that another 470 are injured (Figure 3-5, Chapter 3).

Mirrors and Other Sensors

To improve the school bus driver's view of the area immediately in front of the bus, NSBSC recommends mirrors on the front corners of all school buses (NSBSC 1985, 23). NHTSA makes a similar recommendation in its voluntary highway safety guidelines.[7]

School buses currently sold in the United States are legally required to be equipped with at least one cross-view mirror (Figure 5-7) that meets criteria set forth by NHTSA (49 CFR 571.111, §9.2).

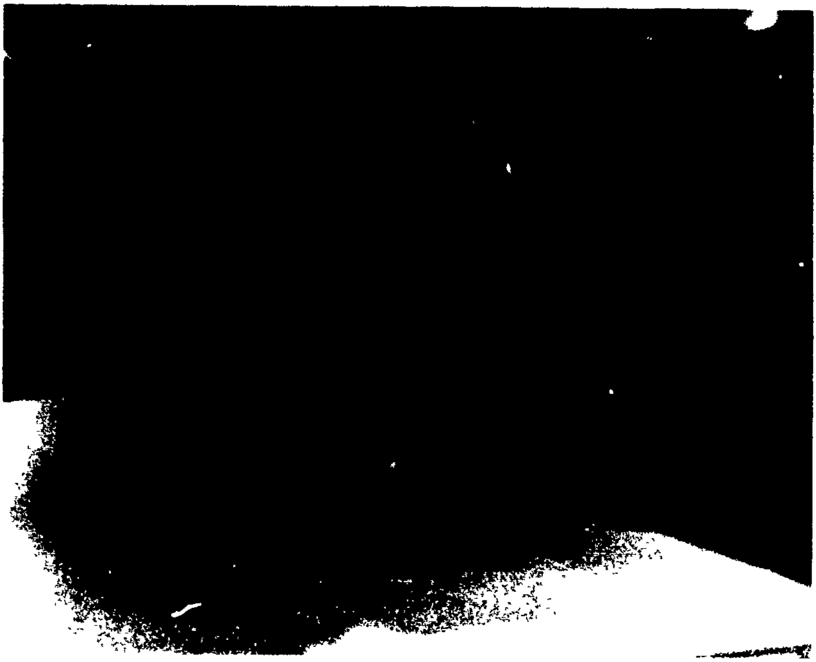


FIGURE 5-7 Cross-view mirrors are standard equipment on school buses.

The required cross-view mirror may provide the driver a better view of children in front of the bus (e.g., students who fall down or who stoop to pick up an object while crossing the street). These mirrors might be improved, however. "The exact minimum type and number of convex mirrors cannot now be specified . . . because the definitive controlled research on this subject has not yet been performed" (Hale et al. 1983, 31).

Although mirrors that allow drivers to see in front of school buses are generally believed to be worthwhile and have become standard school bus equipment, no evaluation of the effectiveness of mirrors in reducing pedestrian accidents has been conducted.

The committee believes that the installation of cross-view mirrors on school buses has reduced the frequency with which children are struck by their own buses. Further research, however, may be needed to optimize the number, type, and characteristics of cross-view mirrors installed on buses.

To better detect objects (including children) around and beneath the bus, several companies are now marketing electronic (i.e., radar, microwave, ultrasonic, or other) systems to alert drivers when such objects are present. If an object is detected near the bus as it pulls away from a stop, an alarm is sounded to warn the driver of the potential danger.

As an alternative to electronic systems, another company is marketing a mechanical system that will stop the school bus automatically when objects are detected beneath the wheels. This system consists of two plastic shields mounted on the bus—one on the front bumper and the other in front of the right rear wheels. Both shields extend to within 6 in. of the ground and serve as mechanical switches to detect the presence of children (or other objects) immediately in front of the wheels. When either shield is deflected, the brakes on the bus are automatically activated.

Both the electronic and mechanical sensor systems are equipped with logic circuitry that allows the devices to operate at low speeds (speeds typical of a bus pulling away from a loading zone) and prevents them from operating at higher speeds when a false positive signal might be harmful.

Although no real-world evaluations have been conducted of electronic and mechanical sensors designed to detect objects around and beneath school buses, the committee believes that such systems would reduce school bus and pedestrian accidents.

Barriers

Another device that has been marketed to reduce school bus and pedestrian accidents is the crossing control arm. The crossing control arm is mounted on the front bumper of school buses (Figure 5-8). When the door of a school bus is opened to admit or discharge students, the control arm swings out for a distance of several feet, becoming an obstacle that students must walk around in order to cross the road in front of the bus.

Crossing in front of the bus, the students are forced by the crossing control arm to move farther out from the front bumper of the bus where they are more easily seen by the driver.

This device, like other devices marketed to reduce the likelihood that a school bus will strike a child, has an intuitive appeal. The committee believes that the device would provide children, particularly young (small) children, additional protection in loading zones, but like the other devices reviewed, crossing control arms have not been evaluated to measure their effectiveness in reducing the number of school bus and pedestrian accidents.

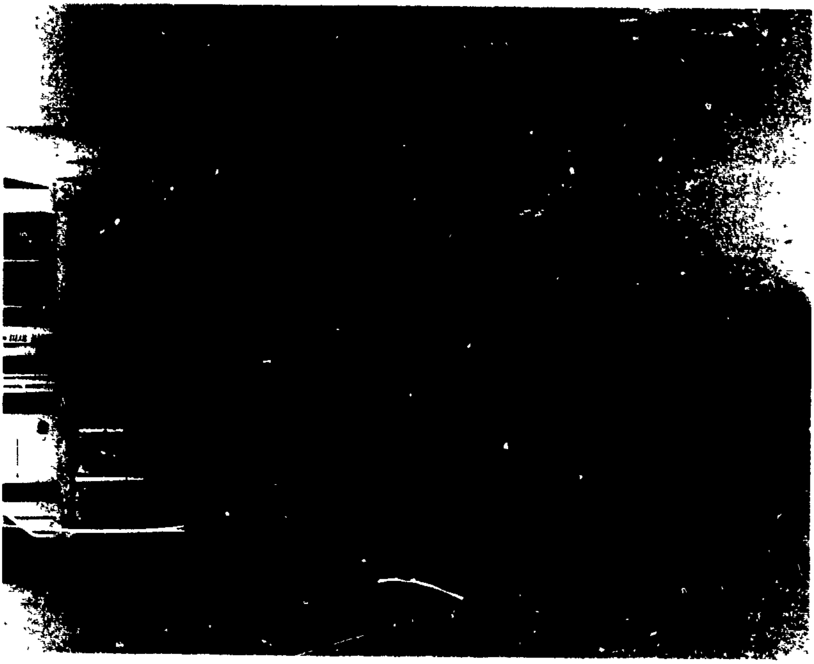


FIGURE 5-8 Crossing control arm mounted on front bumper of school bus (in open position).

School Bus Routes and Stops

In addition to behavioral and physical measures, school bus routes and stops can be located so that the potential for pedestrian accidents in school bus loading zones is reduced. The basic principles that school districts should follow have been known for decades (NSC 1980):

- School buses should not be required to back up on their routes.
- Stops should be located to minimize traffic disruptions and to afford the driver a good field of view in front of and behind the bus.
- Stops should be located to minimize the need for children to cross in front of the bus to board or leave the bus, particularly on busy highways.

Although the importance of safety-conscious route planning is apparently well recognized, no research or systematic studies are available that estimate the safety benefits of such practices or address the trade-offs between operational efficiency and safety.

Summary

Each year 38 children are killed and another 800 are injured in school bus loading zones. Approximately two-thirds of these children are killed by school buses, or vehicles used as school buses, and one-third are killed by other vehicles. Both behavioral and physical measures have been promoted to reduce the frequency of school bus and pedestrian deaths and injuries.

Programs to better select and train school bus drivers have been developed at both the federal and state levels. These programs clearly have the potential to reduce school bus accidents in general and pedestrian accidents in particular. No studies or data are available, however, that provide a basis for estimating the effectiveness of these programs in reducing the number of school bus accidents.

NHTSA recommends that school bus safety instruction be provided to children on at least a semiannual basis. NHTSA and other organizations have developed behavior-based educational programs to provide this instruction. Yet, many school districts provide little if any instruction in school bus safety. No studies have been conducted to measure the effectiveness of behavior-based educational programs specifically for reducing the number of school bus and pedestrian accidents; however, evaluations of other pedestrian education programs for children indicate encouraging results.

School bus monitors offer another means of altering behavior to reduce school bus and pedestrian accidents. The major objection to the use of school bus monitors is cost. As an alternative, California requires school bus drivers to escort students in grades K through 8 across streets and highways when they leave the school bus. Comparisons of school bus accident data from California and other states suggest that the California escort program has been effective in reducing pedestrian deaths and injuries, perhaps substantially.

Four classes of physical measures designed to prevent pedestrian accidents were reviewed in this chapter. The first two classes—signals (e.g., eight-light systems, stop signal arms, strobe lights) and communications equipment (e.g., external loud speaker systems)—are intended to reduce the frequency of accidents involving children being struck by other vehicles. The various signals that are installed on school buses are intended to warn other vehicles that a child may be crossing in front of the bus. Communications equipment (i.e., external loud speakers) is intended to aid children in crossing a street or highway when they board or leave a school bus by substituting the driver's judgment for the child's about when it is safe to cross the street or highway.

The second two classes of physical measures designed to reduce the number of pedestrian accidents—sensors (e.g., cross-view mirrors, electronic and mechanical sensors) and barriers (e.g., crossing control arms)—are intended to reduce the number of accidents involving children being struck by their own bus.

Although all of the physical devices to reduce pedestrian accidents reviewed in this chapter have been installed on operational school buses, the degree to which any of these devices will reduce the number of pedestrian accidents, and the deaths and injuries that result from these accidents, is not well known. The committee believes, however, that all of these measures are likely to have a positive effect on safety, and that the electronic and mechanical sensors and the crossing control arm are particularly promising.

In addition to using behavioral and physical measures, school districts can red·· the potential for pedestrian accidents in school bus loading zones by c· .ul planning of routes and stops. Despite the obvious link to safety, no .idies are available that estimate the safety effects of different route and bus stop characteristics.

Notes

1. Presentation to Committee by Ron Kinney, State Director of Pupil Transportation, State of California, September 7, 1988.
2. The school bus–pedestrian fatalities shown in Figure 5-3 might have been normalized by the number of student passengers transported, but the passenger data available are of unknown consistency and reliability. Instead, Figure 5-3 shows the total number of school bus accident fatalities in each state to illustrate the relative frequency of school bus–pedestrian fatalities. Pedestrian fatalities were not divided by total fatalities because of the small numbers involved and the inherent instability from year to year of school bus accident fatalities.
3. Minimum standards set at the 1985 NSBSC do not carry the weight of law and have not been adopted in all states. California, for example, does not require that buses have flashing amber warning lights.
4. Data supplied by Thomas Built Buses [letter from M. B. Mathieson, Director of Engineering, Thomas Built Buses, to the Transportation Research Board (TRB), May 23, 1988.]
5. Letter and data from Carlisle Beasley, Director of Transportation, Metropolitan Public Schools, Nashville, to Ernest Farmer, State Director of Pupil Transportation, Nashville, Tennessee, October 11, 1983.
6. Letter from John I. Goss, Director of District Operations for the Marana (Arizona) Unified School District, to TRB, October 21, 1987.
7. Highway Safety Program Standard 17, voluntary guidelines issued under the Highway Safety Act (23 CFR No. 17) that cover a wide range of subjects including school bus identification, operation, and maintenance. NHTSA does not require compliance with these guidelines under the Highway Safety Act; however, it does recommend that an individual state adopt the guidelines as its own policy governing student transportation programs. In addition to this guideline, NHTSA has developed Highway Safety Program Manual 17, a companion document that provides more detailed information than the three-page Standard 17.

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ABBREVIATIONS

KDOT	Kansas Department of Transportation
NHTSA	National Highway Traffic Safety Administration
NSBSC	National School Bus Standards Conference
NSC	National Safety Council

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6 Cost-Effectiveness of School Bus Safety Measures

A NUMBER OF MEASURES to enhance school bus safety have been reviewed in the previous two chapters. Safety programs and devices designed to reduce passenger deaths and injuries are reviewed in Chapter 4; and safety programs and devices intended to protect children as they board or leave school buses are reviewed in Chapter 5. Building on the reviews in Chapters 4 and 5, this chapter contains safety cost-effectiveness estimates for selected school bus safety measures.[1]

1. Seat belts,
2. Higher seat backs,
3. School bus monitors,
4. Crossing control arms,
5. Electronic sensors,
6. Mechanical sensors,
7. Stop signal arms,
8. External loud speaker systems, and
9. Pupil education programs.

Estimates of safety cost-effectiveness are presented in two ways. First, the estimates show how many deaths and injuries might be avoided if $1 million were spent annually to implement each measure. For example, if $1 million were available annually for seat belts, how many buses could be equipped and maintained and how many deaths and injuries would be avoided? Second, the estimates show the annual cost of adopting each measure nationwide and the reductions in the numbers of deaths and injuries that would be expected. For example, how much would it cost to equip and maintain all school buses in the United States with seat belts, and what would be the expected reductions in the numbers of deaths and injuries? For some measures, such as seat belts and higher seat backs that should be installed as original equipment on new school buses, nationwide use could not be achieved for a number of years. In such cases the estimates represent the annual costs of installation and maintenance and expected safety benefits after nationwide use is achieved.

For all of the measures considered, the analyses assume a 15-year service life with no salvage value and use a discount rate of 5 percent per year. Analysis assumptions about the target population of deaths and injuries that each measure addresses and the range of likely effectiveness of the measures in reducing these deaths and injuries are discussed next. Further analysis assumptions and methods are described in Appendix E.

Target Populations

School bus safety measures often address different target populations of student deaths and injuries from school bus accidents. For example, a crossing control arm on the front of a bus is intended to prevent students from being struck by the front of the bus after they leave the bus. It will not reduce the number of fatalities and injuries sustained by school bus passengers during crashes, nor will it help students who are struck by the side of the bus or fall under the rear wheels.

For the nine measures for which safety cost-effectiveness analyses were prepared, the data in Table 6-1 identify various target populations and the annual number of fatalities and injuries that occur in these populations. The numbers of fatalities and injuries shown for each measure are based on data presented in Chapter 3.

For example, the target population for seat belts is student passengers in Type I school buses [buses with a gross vehicle weight rating (GVWR) greater than 10,000 lb]. For this population, there are 10 fatalities and 427 incapacitating injuries each year. If seat belts were 100 percent effective and consistently worn by all student passengers, all of these fatalities and incapacitating injuries would be avoided. Realistically, however, the effectiveness is less than 100 percent and many students will probably not always wear seat belts, so the expected numbers of deaths and injuries avoided are lower, as reported later.

The data in Table 6-1 reemphasize a point made in Chapter 3: more children are killed as pedestrians in loading zones outside the bus than while riding as passengers inside the bus. If the cost and effectiveness of the various safety

TABLE 6-1 TARGET POPULATIONS OF FATALITIES AND INJURIES ADDRESSED

Safety Measures	Target Population (Student)	Annual Pupil Fatalities	Annual Pupil Injuries		
			Incapacitating	Nonincapacitating	Possible
Seat belts	Passengers in Type I buses	10	475	2,375	6,650
Higher seat backs	Passengers	12	475	2,375	6,650
School bus monitors	Passengers and pedestrians	50	637	2,618	7,053
Crossing control arms	Pedestrians struck by the fronts of school buses[a]	16	37	57	95
Electronic sensors	Pedestrians struck by school buses	24	57	85	141
Mechanical sensors	Pedestrians struck by school buses	24	57	85	141
Stop signal arms	Pedestrians struck by other vehicles[b]	5	46	70	115
External loud speaker systems	Pedestrians struck by other vehicles	12	105	158	262
Pupil education programs	Pedestrians[c]	31	139	209	347

NOTE: The fatalities and injuries shown are estimates from Table 3-10 and Figure 3-9 in Chapter 3.

[a] Approximately two-thirds of all pupil pedestrians killed by school buses are struck by the front of the bus (SOURCE: Kansas Department of Transportation, Bureau of Personnel Services, Safety Education Section and reprinted in *National School Bus Report*, March 1988, p 13). It is assumed that two-thirds of all pupil pedestrians injured by school buses are struck by the front of the bus.

[b] Stop signal arms are not required in 22 of 50 states (i.e., in 44 percent of the states). Therefore, it is assumed that 44 percent of all children who are killed or injured when struck by other vehicles could potentially benefit from the installation and use of stop signal arms.

[c] In an average year, 31 of 36 fatally injured pupil pedestrians are between 5 and 12 years old (i.e., in grades K through 6), the age group addressed by pupil education programs. It is assumed that 86 percent (31/36) of all pupil pedestrian injuries are sustained by children in grades K through 6.

measures considered are the same, those measures designed to reduce or prevent pedestrian fatalities are better safety investments than measures designed to prevent passenger fatalities.

Although pedestrian fatalities are more common than passenger fatalities, the reverse is true for injuries. More students are injured inside school buses than in loading zones around school buses. Other things being equal, measures designed to reduce student passenger injuries are better investments than measures designed to reduce student pedestrian injuries.

Effectiveness Estimates

The study sought information on the degree to which each of the measures reviewed earlier would reduce the number of deaths and injuries that result from school bus accidents. Unfortunately, little information is available on the effectiveness of most school bus safety measures that is expressed as percent reductions in deaths and injuries. Seat belts have been researched most, and from that research, the committee concluded that the use of seat belts on school buses with GVWRs greater than 10,000 lb (i.e., Type I buses) may reduce the likelihood of deaths and injuries to passengers involved in a school bus crash by up to 20 percent (Chapter 4).

For other measures reviewed in Chapters 4 and 5, any estimates of effectiveness must be more conjectural. To make approximate safety cost-effectiveness comparisons, the committee made judgments about the range of likely effectiveness with respect to the target populations listed in Table 6-1 as follows:

Measure	*Effectiveness (%)*
Seat belts	0–20
Higher seat backs	0–20
School bus monitors	25–75
Crossing control arms	5–25
Electronic sensors	10–50
Mechanical sensors	10–50
Stop signal arms	0–30
External loud speaker systems	0–20
Pupil education programs	0–20

These estimates, combined with information on the costs of the safety measures and the target population of student deaths and injuries that each safety measure addresses, provide the basis for analyses of safety cost-effectiveness estimates presented in the following sections.

Seat Belts

Manufacturers estimate that equipping a typical, 66-passenger, Type I school bus with seat belts at the factory adds about $900 to $1,500 to the cost of the bus,[2] and discussions with manufacturers and school bus operators indicate that annual seat belt maintenance costs are roughly $30 to $35 per bus each year. Assuming an average initial cost per bus of $990 and an annual maintenance cost of $33 per bus, 7,789 Type I school buses could be equipped and maintained with seat belts at an annual cost of $1 million (Appendix E).

If 7,789 school buses were equipped with seat belts, up to 0.023 passenger fatality that occur in Type I school buses each year could be avoided (up to 1 life every 43 years). This estimate is based on the judgments that seat belts, if worn, could reduce fatalities by up to 20 percent and that one-half of the students riding in belt-equipped buses would wear the belts (Chapter 4). By the same reasoning, seat belts would reduce up to 1.1 incapacitating (A-level) injuries, 5.6 nonincapacitating (B-level) injuries, and 15.6 possible (C-level) injuries each year (Appendix E).

The annual cost to equip and maintain all Type I school buses in the United States with seat belts would be about $43 million.[3] Each year, such an investment could save up to one life while reducing up to 48 incapacitating injuries, 238 nonincapacitating injuries, and 665 possible injuries.

Higher Seat Backs

A typical 66-passenger bus can be equipped with 24-in., instead of 20-in. (as measured from the seating reference point), seat backs for an added initial cost of about $150[4]; the added cost to maintain these higher seat backs throughout the life of the bus would be negligible. At these costs, approximately 69,000 school buses could be equipped with higher seat backs for an expenditure of $1 million/year (Appendix E). Assuming that higher seat backs could reduce the number of deaths and injuries by up to 20 percent (Chapter 4), up to 0.426 passenger fatality might be prevented each year (up to 1 life every 2 years). Similarly, a $1 million/year investment in higher seat backs could prevent up to 16.9 incapacitating injuries, 84.3 nonincapacitating injuries, and 236.0 possible injuries each year.

The annual cost to equip all school buses in the United States (Type I as well as other school buses) with higher seat backs is approximately $6 million. Each year, such an investment could save up to 2.4 lives while reducing up to 95 incapacitating injuries, 475 nonincapacitating injuries, and 1,330 possible injuries.

School Bus Monitors

The estimated cost for each school bus monitor is $4,860 per year.[5] For an annual investment of $1 million, about 200 school buses could be supervised by adult monitors (Appendix E).

The effectiveness of school bus monitors in reducing the number of student fatalities both inside and outside the bus is estimated to be between 25 and 75 percent (Chapter 5). Therefore, a $1 million/year monitoring program could reduce 0.007 to 0.020 fatality each year (about 1 life every 50 to 143 years). Similarly it could prevent 0.1 to 0.3 incapacitating injury, 0.3 to 1.0 nonincapacitating injury, and 0.9 to 2.8 possible injuries each year.[6]

The annual cost of putting monitors on the 390,000 school buses operating in the United States would be more than $1.9 billion. Such a national program could save 13 to 38 lives and reduce 159 to 478 incapacitating injuries, 655 to 1,964 nonincapacitating injuries, and 1,763 to 5,290 possible injuries.

Crossing Control Arms

The purchase price of crossing control arms ranges from about $100 to $300, but little reliable information about maintenance costs is available.[7] Assuming that a crossing control arm could be purchased and installed for $200 and maintained at a cost of $20 per year, about 25,000 buses could be equipped and maintained with crossing control arms at an annual cost of $1 million (Appendix E). If this device prevents 5 to 25 percent of the fatalities that occur when children are struck by their own buses (Chapter 5), its use on 25,500 buses would save 0.052 to 0.261 life each year (about 1 life every 4 to 19 years). Similarly, 0.1 to 0.6 incapacitating injury, 0.2 to 0.9 nonincapacitating injury, and 0.3 to 1.6 possible injuries could be reduced each year.

The number of school buses presently equipped with crossing control arms is unknown but probably represents a small proportion of the total fleet. Assuming that no buses are presently equipped with crossing control arms, all 390,000 school buses in the United States could be equipped with this device for about $15 million/year. Such an investment could save 0.8 to 4.0 lives per year while reducing 2 to 9 incapacitating injuries, 3 to 14 nonincapacitating injuries, and 5 to 24 possible injuries.

Electronic Sensors

Electronic devices to detect the presence of a child near a school bus can be installed for about $1,600 per bus.[8] At this cost and an assumed maintenance cost of $80 per year, about 4,300 buses could be equipped with electronic sensors (Appendix E). If this device reduces the number of fatalities and injuries to children struck by the front or rear of school buses by 10 to 50 percent (Chapter 5), its use on 4,300 buses could prevent 0.026 to 0.131 fatality each year (about 1 life every 8 to 38 years). In addition, 0.1 to 0.3 incapacitating injury, 0.1 to 0.5 nonincapacitating injury, and 0.2 to 0.8 possible injury could be prevented each year.

Installing and maintaining electronic sensors on the 390,000 school buses now operating in the United States would cost approximately $91 million/year. For this expenditure, 2.4 to 12.0 deaths, 6 to 29 incapacitating injuries, 9 to 43 nonincapacitating injuries, and 14 to 71 possible injuries could be prevented each year.

Mechanical Sensors

One company currently manufactures a mechanical device to detect the presence of a child around a school bus and to automatically apply the brakes of the bus when a child is detected. This device is sold for $2,295.[9] At this initial cost, and an assumed maintenance cost of $115/year, about 3,000 buses could be equipped with mechanical sensors and maintained at an annual cost of $1 million (Appendix E).

If this device reduces by 10 to 50 percent the fatalities that result when children are struck by school buses (Chapter 4), its use on 3,000 buses would prevent 0.018 to 0.092 fatality each year (about 1 life every 11 to 56 years). At these same levels of effectiveness, up to 0.2 incapacitating injury, 0.1 to 0.3 nonincapacitating injury, and 0.1 to 0.5 possible injury could be avoided each year.

To equip and maintain with mechanical sensors the 390,000 school buses now operating in the United States would cost more than $131 million/year. Such a device could save 2.4 to 12.0 lives per year while preventing 6 to 29 incapacitating injuries, 9 to 43 nonincapacitating injuries, and 14 to 71 possible injuries.

Stop Signal Arms

At present, 22 states (44 percent) do not require stop signal arms on school buses. The analysis presented here assumes that 44 percent of the 390,000 buses in the United States (172,000) are not equipped with stop signal arms. Similarly, the analysis assumes that of those children struck and killed or injured by other vehicles in school bus loading zones, 44 percent were leaving or boarding school buses that are not equipped with stop signal arms. This results in 5 fatalities, 41 incapacitating injuries, 62 nonincapacitating injuries, and 103 possible injuries each year.

Stop signal arms can be installed for about $200 per bus.[10] At this initial cost and assuming an annual maintenance cost of $10 per bus per year, about 34,000 buses can be equipped and maintained with stop signal arms at an annual cost of $1 million/year (Appendix E). If up to 30 percent of the deaths of and injuries to children in loading zones could be reduced by using stop signal arms (Chapter 5), installing them on 34,166 buses could prevent up to 0.299 fatality each year (up to 1 life every 3 years). Similarly, up to 2.8 incapacitating injuries, 4.2 nonincapacitating injuries, and 6.9 possible injuries could be avoided each year.

Stop signal arms could be installed and maintained on an estimated 172,000 school buses not presently equipped with stop arms at an annual cost of $5 million. This expenditure could save 0 to 1.5 lives each year while preventing 0 to 14 incapacitating injuries, 0 to 21 nonincapacitating injuries, and 0 to 35 possible injuries each year.

External Loud Speaker Systems

External loud speaker systems, which drivers can use to tell children when it is safe to cross the street, can be installed on school buses for about $200.[11] Assuming an annual maintenance cost of $10/year, about 34,000 buses could be equipped with these systems at an annual cost of $1 million (Appendix E). If these systems, properly used, prevent up to 20 percent of the fatalities and injuries that result when children are struck by other vehicles (Chapter 5), equipping 34,166 buses with the systems would save up to 0.210 of the lives lost in this type of accident each year (up to 1 life every 5 years). Similarly, use of external loud speakers on 34,166 buses could reduce up to 1.8 incapacitating injuries, 2.8 nonincapacitating injuries, and 4.6 possible injuries each year.

All of the school buses in the nation's fleet could be equipped and maintained with external loud speaker systems for approximately $11 million/year. This expenditure could save 0 to 2.4 lives each year and prevent 0 to 21 incapacitating injuries, 0 to 32 nonincapacitating injuries, and 0 to 5.2 possible injuries.

Pupil Education Programs

Of the 25 million children transported to and from school by bus, approximately 14 million are in grades K through 6, for which pupil education programs would be most effective. Pupil education programs could be conducted at an additional cost of about $1 per student per year so that 1 million students in grades K through 6 could receive this added instruction at an annual cost of $1 million. If this instruction, in addition to any instruction pupils are now receiving, reduced pupil fatalities in loading zones by up to 20 percent, a $1 million/year program could save up to 0.459 life annually (up to 1 life every 2 years). Similarly, it could reduce up to 2.1 incapacitating injuries, 3.1 nonincapacitating injuries, and 5.1 possible injuries each year.[12]

The 14 million school bus passengers in grades K through 6 could receive additional pedestrian education for $14 million/year. Such an expenditure could save up to 6 lives while reducing up to 28 incapacitating injuries, 42 nonincapacitating injuries, and 69 possible injuries each year.

Summary

This chapter contained the results of safety cost-effectiveness analyses for nine school bus safety measures for which sufficient information was available to estimate the likely effects on accidents and resulting fatalities and injuries. The data in Tables 6-2 and 6-3 summarize these results.

Based on the upper end of the effectiveness range, the measures that offer the greatest potential safety improvement per dollar invested are higher seat backs and pupil education programs. For an expenditure of $1 million annually, either of these measures could save up to 0.5 life each year, or up to 1 life every 2 years. In addition, higher seat backs could be particularly cost-effective in reducing injuries (Table 6-2). The measures that offer the smallest safety improvement per dollar invested are seat belts and school bus monitors. For a $1 million/year expenditure, neither could save more than 0.023 life per year, or up to 1 life every 43 years (Table 6-2).

The most costly measure to implement nationwide would be school bus monitors, with an annual cost of about $1.9 billion. If all school buses in the United States were staffed with adult monitors, up to 38 lives might be saved and 478 serious (incapacitating) injuries prevented each year (Table 6-3).

The least costly measures to implement nationwide are higher seat backs and stop signal arms. Either of these safety measures could be implemented nationwide at a cost of $6 million/year or less. If higher seat backs were available on all school buses, 2 to 3 lives might be saved and as many as

TABLE 6-2 REDUCTIONS IN FATALITIES AND INJURIES FROM AN ANNUAL INVESTMENT OF $1 MILLION PER MEASURE

Safety Measure	Effectiveness[a]	Lives Saved	Injuries Prevented		
			Incapacitating	Nonincapacitating	Possible
Seat belts[b]	0–20	0–0.023	0–1.1	0–5.6	0–15.6
Higher seat backs	0–20	0–0.426	0–16.9	0–84.3	0–236.0
School bus monitors	25–75	0.007–0.020	0.1–0.3	0.3–1.0	0.9–2.8
Crossing control arms	5–25	0.052–0.261	0.1–0.6	0.2–0.9	0.3–1.6
Electronic sensors	10–50	0.026–0.131	0.1–0.3	0.1–0.5	0.2–0.8
Mechanical sensors	10–50	0.018–0.092	0–0.2	0.1–0.3	0.1–0.5
Stop signal arms	0–30	0–0.299	0–2.8	0–4.2	0–6.9
External loud speaker systems	0–20	0–0.210	0–1.8	0–2.8	0–4.6
Pupil education programs	0–20	0–0.459	0–2.1	0–3.1	0–5.1

[a] Percent reduction in deaths and injuries of target populations given in Table 6-1.
[b] Fifty percent use rate assumed.

TABLE 6-2 ANNUAL COSTS FOR NATIONWIDE USE AND REDUCTIONS IN FATALITIES AND INJURIES

Safety Measure	Effectiveness[a]	Annual Cost ($ millions)[b]	Lives Saved	Injuries Prevented: Incapacitating	Injuries Prevented: Nonincapacitating	Injuries Prevented: Possible
Seat belts[c]	0–20	43	0–1.0	0–48	0–238	0–665
Higher seat backs	0–20	6	0–2.4	0–95	0–475	0–1,330
School bus monitors	25–75	1,900	12.5–37.5	159–478	655–1,964	1,763–5,290
Crossing control arms	5–25	15	0.8–4.0	2–9	3–14	5–24
Electronic sensors	10–50	91	2.4–12.0	6–29	9–43	14–71
Mechanical sensors	10–50	131	2.4–12.0	6–29	9–43	14–71
Stop signal arms	0–30	5	0–1.5	0–14	0–21	0–35
External loud speaker systems	0–20	11	0–2.4	0–21	0–32	0–52
Pupil education programs	0–20	14	0–6.3	0–28	0–42	0–69

[a]Percent reduction in deaths and injuries of target populations given in Table 6-1.

[b]For stop signal arms, the data in this table assume that 56 percent of the nation's school bus fleet is already equipped. For other measures, current use is low enough to disregard.

[c]Fifty percent use rate assumed.

95 serious (incapacitating) injuries prevented each year. If stop signal arms were installed on all school buses not presently equipped with this device, up to 1 to 2 lives could be saved each year and up to 14 serious injuries could be prevented (Table 6-3).

Seat belts could be installed and maintained in all Type I school buses operated in the United States at an annual cost of $43 million. For this investment, 1 life might be saved and up to 48 serious injuries prevented in an average year.

Notes

1. Measures were selected for which reliable cost information is available and approximate effectiveness ranges could be estimated, and as a consequence some promising measures were excluded. Rear-facing seats, for example, were excluded because neither reliable cost nor effectiveness information is available. The California escort program was excluded primarily because program costs are unknown. Also, although comparisons of statewide accident data suggest that the California program has a favorable effect on pedestrian accidents, the effectiveness of the program has not been measured.
2. Thomas D Turner, Manager, Engineering Services, Blue Bird Body Co., estimated the cost at $1,200 to $1,500 per bus (letter dated March 24, 1988). C. Morris Adams, Vice President for Marketing and Corporate Affairs, Thomas Built Buses, Inc. estimated the cost at $14 per belt, or $924 for a 66-passenger bus (letter dated March 17, 1988). Jerry D. Williams, President of American Transportation Corporation, estimated the cost at $22.42 per belt, or $1,479.72 for a 66-passenger bus (letter dated May 17, 1988).
3. Based on a total school bus fleet of 390,000 of which 331,500 (85 percent) are estimated to be Type I school buses.
4. The cost of a school bus passenger seat of standard seat back heights (20 in.) is estimated to be $88.84; the cost of a seat with a 24-in. back is $95.68, a differential of $6.84 per seat, or $150.48 for a 66-passenger bus. These costs were provided in a letter from Malcolm B. Mathieson, Vice President for Engineering, Thomas Built Buses, Inc., to the Transportation Research Board (TRB), October 19, 1988.
5. The $4,860 annual salary for school bus monitors is based on a wage rate of $5.40/hr for a 5-hr day throughout a 180-day school year. Estimate provided by Kyle E. Martin, Mayflower Contract Services, April 15, 1988.
6. These estimates assume that monitors are randomly assigned to school buses. If monitors were assigned disproportionately to buses carrying younger children, the estimated number of lives saved and injuries reduced would rise.
7. Tidwell Garnston, Sale Engineer, Specialty Manufacturing Co., Inc. estimates the cost of air/vacuum control arms at $125 to $150 and electronically driven arms at $250 to $300 (telephone conversation February 10, 1988). Nathan Sobler, Sales Manager, School Parts Co. estimates the cost of air/vacuum control arms at $100 to $150 and electronically driven arms at $225 (telephone conversation February 5, 1988).

8. Wayne Durley, President, CARE, Inc., estimated cost at $1,550 (telephone conversation February 19, 1988). Estimate of $1,600 provided by Alan Hersch, President, Safety First, Ltd. (letter dated January 27, 1988).
9. Price quote of $2,295 provided by John Atkinson, President, Insta Brake, Inc. (conversation on September 7, 1988).
10. Based on a range of prices from two manufacturers: Tidwell Garnston, Sales Engineer, Specialty Manufacturing Co., Inc., $125 to $300 (February 10, 1988) and Nathan Sobler, Sales Manager, School Parts Co., $100 to $225 (February 5, 1988).
11. Chris Madonia, Sales Manager, Midwest Electronic Industries, estimated the cost of an external speaker system at $150 to $230 (letter dated October 9, 1987).
12. Thirty-one of 36 fatally injured student pedestrians are between the ages of 5 and 12 (i.e., grades K through 6), based on the data in Figures 3-2 and 3-3, Chapter 3. This analysis assumes that 86 percent (31/36) of all student pedestrian injuries are sustained by children in grades K through 6.

7 Conclusions and Recommendations

COMPARED TO OTHER SURFACE modes, school bus transportation has a good safety record. Even though school buses transport more passengers per trip, the rate of occupant fatalities per mile driven for school buses is about one-fourth that for passenger cars. School bus transportation is already quite safe, but several steps can be taken to make it even safer. These steps involve modifying some federal standards, applying or upgrading several safety measures the worth of which has already been sufficiently demonstrated, and developing and evaluating promising new products and programs.

School Bus Passenger Protection

Post-1977 School Buses

In 1977 the National Highway Traffic Safety Administration (NHTSA) issued several new school bus safety standards that substantially upgraded the crashworthiness of school buses. The committee recommends that all pre-1977 school buses (i.e., buses manufactured before April 1, 1977) still being operated by individual school districts and private contractors be replaced as rapidly as possible. States are encouraged to speed replacement of pre-1977 school buses. School districts and contractors that are operating both pre- and post-1977 buses should use the post-1977 buses first on those routes and in those situations (e.g., trips for extracurricular activities) in which school bus passengers may be exposed to greater risk.

Replacing the nation's school bus fleet with post-1977 buses will mean that older, pre-1977 buses will become more readily available to private groups such as church groups and boys' and girls' camps. Organizations operating pre-1977 buses should be informed that these buses fail to meet current standards for newly manufactured buses and that the organization should (a) rigorously maintain these older buses and (b) provide safety instruction for all passengers (e.g., vehicle evacuation and use of fire extinguishers). Federal and state agencies should take necessary action to ensure that drivers of pre-1977 buses are adequately trained and appropriately licensed.

Seat Belts

Large, Type I school buses [i.e., buses with gross vehicle weight ratings (GVWRs) greater than 10,000 lb] currently manufactured for sale in the United States are not required to be equipped with seat belts (i.e., lap belts). New York State now requires that large buses purchased for use within its jurisdiction be equipped with seat belts; Michigan has adopted regulations that discourage local school districts from installing seat belts on school buses. Advocates of seat belts claim that lives would be saved and injuries avoided if seat belts were standard equipment on school buses and if policies were established to ensure their use. Opponents claim that seat belts are costly, would offer little or no additional occupant protection, and might even increase injuries in some crashes.

The committee concludes that the use of seat belts on large, post-1977 school buses may reduce the likelihood of death or serious injury to school bus passengers by up to 20 percent. If all large school buses were equipped with seat belts and students used them 50 percent of the time on average, one life might be saved, and several dozen serious injuries might be avoided each year.

The committee further concludes that the overall potential benefits of requiring seat belts on large school buses are insufficient to justify a federal requirement for mandatory installation. The funds used to purchase and maintain seat belts might better be spent on other school bus safety programs and devices that could save more lives and reduce more injuries (e.g., purchasing buses with higher seat backs and stop signal arms). Most members of the committee believe, therefore, that states and local school districts should not be encouraged to equip new buses with seat belts. Nevertheless, some members of the committee believe that a consistent occupant-restraint policy for all motor vehicles is important enough that states and local school districts should be encouraged to equip new school buses with seat belts.

States and local school districts that require seat belts on school buses must ensure not only that all school bus passengers wear the belts, but that they wear them correctly. Research suggests that any program to require the use of seat belts on school buses can be effective only if it has the support of the school board, school administrators, teachers, parents, and school bus drivers. With this support it is easier to teach children to wear seat belts correctly, and they will be more willing to comply with the requirement that they wear them.

It may be necessary at first to assist young children in tightening and buckling seat belts. Such assistance might be provided by adult monitors or responsible older children.

Current federal standards that describe how seat belts should be installed on school bus passenger seats [Federal Motor Vehicle Safety Standard (FMVSS) 209, Seat Belt Assemblies, and FMVSS 210, Seat Belt Assembly Anchorage] apply only to school buses with GVWRs of 10,000 lb or less. These standards should be modified to include school buses with GVWRs greater than 10,000 lb.

Finally, retrofitting any large school bus with seat belts can present problems. On pre-1977 school buses, seat belts used in conjunction with the lower, less-padded seat backs typical of those buses might actually increase the severity of injuries. Consequently, seat belts should not be installed on buses that were manufactured before April 1, 1977, that is, before FMVSS 222, School Bus Seating and Crash Protection, went into effect. For post-1977 buses, retrofitting with seat belts usually requires strengthening of seat and floor structures and is therefore much more costly than installing seat belts at the factory as original equipment. The committee does not recommend retrofitting post-1977 buses unless those buses are already equipped with seats designed to accommodate belts.

Other Seat and Restraint Measures To Enhance Passenger Safety

Three additional school bus seat and restraint systems were considered that are intended to better restrain or distribute the forces acting on school bus passengers during a collision: (a) "lap bar" restraint systems, (b) lap and shoulder belt systems, and (c) rear-facing seats with lap belts. Both the lap bar and the lap-shoulder belt systems are intended to provide added protection, beyond that provided by lap belts, by better restraining school bus passengers and reducing the likelihood that their heads will strike the seat backs in front of them. Rear-facing seats (with higher seat backs and lap belts) are intended to better direct and distribute the forces acting on school bus passengers during a frontal collision.

Of the three systems, rear-facing seats appear to pose the fewest technical problems. Lap bars present many technical problems; therefore, the committee doubts that they will ever be a viable alternative to the seat belt. All of these systems will require further research and testing before they are considered for general use. Although such systems may further enhance school bus passenger protection, the occupant protection that is built into school buses manufactured since 1977 is already substantial, and the safety record of these buses is very good. As a result, the marginal costs of additions and modifications to the seat and restraint systems on these buses must be kept low if they are to be safety cost-effective.

Seat Back Height

Following a series of school bus crash tests at the University of California at Los Angeles in the 1960s, researchers recommended that school bus seat backs be at least 28 in. high, or approximately 24 in. above the seating reference point (SRP), as measured by federal regulations.

In a separate investigation, NHTSA concluded that school bus passengers were provided a "reasonable level of protection" with 20-in. seat backs. FMVSS 222, School Bus Seating and Crash Protection, which became effective April 1, 1977, set the minimum school bus seat back height at 20 in., as measured from the SRP (see Chapter 4). Although it acknowledged that higher seat backs might provide additional occupant protection, NHTSA was concerned that higher seat backs might make it more difficult for drivers to see students and to monitor student behavior. In addition, some school bus manufacturers have noted that higher seat backs might obstruct window emergency exits—and thus fail to comply with certain provisions of FMVSS 217, Bus Window Retention and Release. Nevertheless, two states (New York and Illinois) now buy buses with the higher, 24-in. seat backs and report no operational problems.

The committee believes that the operational objections to higher seat backs have not been supported by field experience and that they can be installed in a manner consistent with NHTSA standards. It recommends that the minimum school bus seat back height be raised from 20 to 24 in measured from the SRP. By raising seat backs to this height, school bus passengers will be provided additional crash protection in both frontal and rear-end collisions at little added cost (about $150) to the purchase price of a school bus.

Standees

If the crash protection measures mandated by the various federal standards (e.g., FMVSS 220, 221, and 222) are to be effective in reducing injuries, it is essential that all passengers be properly seated. Passengers who are out of position during a school bus crash may sustain unnecessary injuries while endangering others as they are thrown about inside the passenger compartment.

Several states have enacted laws that prohibit school bus operators from allowing passengers to stand in the aisle. In other states, standees are permitted when school bus seating capacity is exceeded. The committee recommends that all states prohibit standees on school buses operated by or for public or private schools.

Structural Integrity

In 1977 two federally mandated school bus safety standards, FMVSS 220, School Bus Rollover Protection, and FMVSS 221, School Bus Body Joint Strength, went into effect. Both of these standards are intended to enhance the structural crashworthiness of school buses.

The committee believes that these two standards have significantly enhanced the safety of school bus passengers. However, further enhancements may be feasible, particularly to provide better protection against side impacts from heavy trucks and other large vehicles that are involved in many fatal school bus crashes. Additional research should be undertaken to determine the feasibility of (a) improving the perimetric structure of school buses for greater side-impact protection and (b) making various body components, such as ventilation spaces and access panels that are currently exempt from the safety provisions of FMVSS 221, less hazardous during crashes.

Emergency Exits

FMVSS 217, Bus Window Retention and Release, requires that all school buses have at least one emergency exit door in addition to a right-front passenger service door. The emergency exit door may be located at the rear or on the left side of the bus. If the emergency exit door is located on the left side of the bus, a "push-out" window is required at the rear of the bus. On conventional school buses with front engines, the emergency exit door is located at the rear of the bus. But on transit-type school buses with rear engines, the emergency exit door is located on the left side of the bus, and a hinged, push-out window is provided at the rear of the bus.

The requirements for number and location of emergency exit doors on school buses are independent of the seating capacity. Thus, whether a school bus is designed to carry 20 passengers or 90 passengers, it is required to have only one emergency e it door in addition to the right-front service door.

In its current review of FMVSS 217, NHTSA should reconsider the minimum number of emergency exits required on school buses. Buses with greater seating capacities should have more emergency exits.

In addition, NHTSA should prohibit the installation of seats that obstruct emergency exit doors. Under current regulations, a manufacturer may install passenger seats that obstruct left-side emergency doors, even though school buses with left-side emergency doors are usually high-capacity buses with seating for up to 90 passengers.

Finally, states and local school districts are encouraged to conduct emergency school bus evacuation drills at least twice each school year, as recommended by NHTSA.

Interior Materials

Post-crash fires in school buses are rare. When fires do occur, however, they are often dramatic and of obvious concern to the public. To reduce the likelihood of post-crash fires and other incidental fires started by matches or cigarettes, it would be desirable to eliminate all combustible materials from the passenger compartments of school buses.

The energy-absorbing material (polyurethane) that is used in school bus seats to meet the occupant crash protection requirements in FMVSS 222 has undesirable combustive properties. Conventional polyurethane is easily ignited and gives off a dense, black smoke when burned.

Although some other materials (e.g., neoprene) are more difficult to ignite than conventional polyurethane and give off less smoke when burned, they lack the necessary energy-absorbing properties to protect school bus passengers during a crash.

Future research on fire-resistant and fire-retardant materials for aviation and furniture industries may result in the creation of (a) new materials with the necessary energy-absorbing and combustive properties to provide both occupant crash and fire protection and (b) lower-cost, fire-retardant upholstering materials to cover conventional polyurethane foam seats. NHTSA should monitor this research and upgrade the requirements of FMVSS 302, Flammability of Interior Materials, if and when new energy-absorbing, fire-retardant materials become available at little added cost.

Reflective Markings on School Buses

The majority of school bus accidents occur during daylight hours, but more serious school bus accidents tend to occur disproportionately on high-speed roads at night while students are being transported to and from extracurricular activities. The use of reflective materials on the exterior of school buses would make them more visible and might reduce the number of accidents that occur at night.

NHTSA should consider the potential cost and safety effectiveness of reflective materials on school buses and determine the feasibility of setting minimum standards for their use.

Protecting Children as They Board and Leave School Buses

For every child killed as a passenger in a school bus, another three or four are killed in school bus loading zones. Of the children killed in loading zones, two-thirds are struck by school buses. Five- and 6-year-olds appear to be the most vulnerable to being struck by their own school bus.

The accident data show that children are at greater risk of being killed in school bus loading zones (i.e., boarding and leaving the bus) than on board school buses, although for nonfatal injuries the reverse is true. To further enhance the safety of school bus transportation, the school bus loading zone should be studied more closely. Similarly, research programs aimed at reducing pupil transportation deaths and injuries should focus on developing programs and devices to protect children in school bus loading zones.

Driver Training

Although all states have special license or certification requirements that school bus drivers must meet, states differ widely on the amount of training that is required. Some states require no driver training in school bus operation and pupil management. However, other states require formal training (with specified minimum hours of instruction in the classroom and "behind the wheel") before a driver is allowed to operate a school bus.

The committee recommends that all states require formal training of drivers before they are certified to operate a school bus. A major element of this training should be to address the responsibilities of the school bus driver in ensuring the safety of children both inside the bus and in loading zones.

Pedestrian Safety Education

This study concentrated on measures that would enhance the safety of children as they board, ride in, and leave school buses. However, many other children are killed and injured while walking to and from school, playgrounds, and school bus stops, and simply while standing at school bus stops—with no school bus present. Over the last decade NHTSA has developed safety education programs aimed at preventing children from being killed or injured while walking to and from school. Real-world evaluations of these programs indicate that they reduce such accidents, and the cost of these programs (per child) is quite modest.

NHTSA should encourage the use and continued evaluation of behavior-based pupil pedestrian education programs that have been developed (e.g., with federal highway safety funds) and should complete development of the pupil transportation training program it has designed to reduce pupil pedestrian accidents.

Student Crossing Programs

In California, when students in grades K through 8 cross a street or highway after leaving a school bus, they must, by statute, be escorted across the street or highway by the school bus driver. Before escorting students across a street or highway, the driver must set the emergency brake, turn off the engine, turn on the flashing lights, and remove the key from the ignition. When students leave the bus and do not need to cross the street, the driver can stop the bus without turning on the flashing lights; other vehicles are not required to stop.

The number of children killed in school bus loading zones in California over the last few years has been well below the number that would be expected from the experience of states of comparable size (e.g., Texas and New York). The practice of escorting students across streets and highways when they leave school buses, as well as routing the buses to minimize the number of stops at which students have to cross a street or highway, may have been major factors in reducing the number of pedestrian accidents in school bus loading zones in California.

Objections to the California law include longer delays to students and other traffic at bus stops where children must be escorted and leaving children unattended on a parked school bus. Nevertheless, such problems may be more than offset by reductions in pedestrian accidents. Other states are urged to field test similar programs and assess the benefits as well as the costs that might result.

Instead of having school bus drivers escort students across streets and highways, adult monitors could be assigned to school buses to provide the same service, as well as to assist with pupil management on the bus. The cost of employing adult monitors, however, is prohibitive when compared with other programs and devices that might prevent a similar number of deaths and injuries. Therefore, this alternative is not recommended.

School Bus Routes and Stops

School bus routes should be established to provide safe, convenient, and efficient transportation for children traveling to and from school. The basic principles that define safe school bus routes have been known for decades. For example, the school bus should not have to back up on its route, stops should be located to minimize traffic disruptions and to afford the driver a good field of view in front of and behind the bus, and loading zones should be planned so that children need not cross the street or highway in front of the bus. The question is: Are these principles regularly applied?

The committee believes the safety of school bus routes should not be sacrificed for the sake of operational efficiency, student convenience, or political expediency. States and local school districts should review their school bus routes annually and take all practical measures to ensure that the routes have been safely planned and are being followed as intended.

Cross-View Mirrors

Under the provisions of FMVSS 111, Rearview Mirrors, school buses currently manufactured for sale in the United States must be equipped with a convex cross-view mirror that allows the driver to see the area immediately in front of the bus. The purpose of this standard is to prevent school bus–pedestrian accidents that result from the driver's inability to see small children walking immediately in front of the bus.

Most school buses are equipped with a cross-view mirror, as prescribed in FMVSS 111, or some other configuration of mirrors that exceeds the requirements in the standard. Yet, children, particularly younger children, are still being struck and killed by their own school buses. The frequency with which these accidents occur suggests that the mirrors currently used may be inadequate.

NHTSA should study the adequacy of FMVSS 111 to determine if it can be modified to provide the driver a better view of the area in front of and immediately beside the bus.

Stop Signal Arms

Stop signal arms—stop signs with flashing red lights that extend from the left side of the school bus when passengers are boarding and leaving the bus—are now standard equipment on new buses purchased by 28 states. The purpose of stop signal arms is to prevent children from being struck by other vehicles in school bus loading zones.

Evaluations of this device have demonstrated its effectiveness in stopping other traffic at school bus stops and suggest that it would, therefore, reduce the number of schoolchildren struck by other vehicles in loading zones. The committee recommends that NHTSA require installation of stop signal arms on all school buses manufactured for sale in the United States. States and local school districts should consider retrofitting older buses with stop signal arms.

Additional Measures To Prevent Children From Being Struck by School Buses

Several companies market products that alert drivers to the presence of objects beneath or around school buses when they stop in a loading zone. These products rely on radar, microwave, ultrasonic, or other systems to detect children (or objects) that might be struck by a school bus as it leaves a loading zone and to sound an alarm to warn the driver of the potential hazard.

Another company markets a mechanical device that attaches to the front bumper of the bus and in front of the rear wheels. This device—a plastic shield extending from the bumper to within 6 in. of the ground—functions as a sensor to detect the presence of children (or other objects) immediately in front of the wheels. When the sensor is deflected, the brakes on the school bus are automatically applied.

The most common, and least expensive, mechanical device to prevent school bus and pedestrian accidents is the crossing control arm. The crossing control arm is a device that swings out from the front bumper of the school bus to create an obstacle that children must walk around. By forcing children to walk around the arm, they are kept in the driver's field of vision.

All of these devices have merit and are worthy of further consideration and evaluation. NHTSA, individual states, and local school districts are urged to field test these devices and assess the benefits and costs associated with each.

Additional Measures To Prevent Children From Being Struck by Other Vehicles

Although stop signal arms are recommended as standard equipment on all new buses, evidence suggests that a stop signal arm can be made even more effective by replacing the two alternately flashing red lights on it with red strobe lights. NHTSA should evaluate the added benefit, as well as any operational costs, that may result from the use of red strobe lights in lieu of alternately flashing red lights on stop signal arms.

As a further aid to protecting children from other traffic in school bus loading zones, the use of external loud speakers to communicate with children who have left the bus was considered. This device could be used to tell the child in front of the bus when it is safe to cross the street or highway. The loud speaker system has the potential to reduce accidents as well as the potential to be misused. Local school districts and private contractors are encouraged to experiment with this device and evaluate its potential benefits and costs.

School Bus Standardization

A number of the study recommendations merit field testing and evaluation of different safety devices used on school buses (e.g., red strobe lights on stop signal arms, external loud speaker systems) or retaining some measures (e.g., seat belts) as options for states and local school districts. In making these recommendations, the committee realizes that additional variability in the construction of school buses might result. Nevertheless, the committee urges the states, in cooperation with NHTSA, to work toward more universally acceptable standards for school bus construction and school bus equipment. Nonuniformity of school bus standards across states adds to the cost of each school bus sold and makes the purchase of newer, safer buses more expensive.

School Bus Accident Data

Finally, this study was seriously hampered by a lack of reliable and valid school bus accident data and a dearth of information on the effectiveness of potential school bus safety programs and devices. The committee recommends that NHTSA work with the states and other interested parties to upgrade and standardize school bus accident data collected by the states. As the quality of school bus accident data improves, the committee recommends that these data be used to better define why and how children are being injured in school bus accidents, and to evaluate the effectiveness of various school bus safety programs and devices in reducing the number of accidents, deaths, and injuries.

APPENDIX A

School Bus Accidents

In his 1977 report to the U.S. Congress, Secretary of Transportation William Coleman stated that (NHTSA 1977, VII-2):

> Wholly reliable information on school bus accidents is not readily available on a national basis. This is particularly true for nonfatal injury accidents, and even more so for accidents in which no injury is present. The information deficiency exists with respect to descriptive statistics as well as to accident-injury causation data; and it stems from both inadequate investigation at the accident site and the lack of a formal and systematic data collection and synthesis process to produce aggregated information.

In 1989, 12 years after the secretary's report, national statistics on school bus accidents are still inadequate, and there is no standard definition of school bus accident or school bus-related accident.

During the 1986–1987 school year, California recorded 2,441 school bus accidents, which included only those accidents that involved school buses with students on board. At the request of the committee, the California Highway Patrol reanalyzed its accident data and included accidents that involved school buses with no students on board. As a result of this reanalysis, some 707 additional accidents and three fatalities were found.[1]

In Maryland 5,214 school bus accidents were recorded between school years 1981–1982 and 1985–1986. Some 2,370 (45 percent) of those accidents occurred with no students on board school buses (MDOE 1986, 14).

Clearly California and Maryland have widely divergent definitions of school bus accidents. In California, school bus accidents in which no students were on board the bus are not considered school bus accidents, whereas in Maryland, almost one-half of all school bus accidents involve buses with no students on board.

Other differences in school bus accident data can be found among different states. In Table A-1 the relative percentages of accidents that result in injuries or deaths are given for 12 states. In 1987 Maryland reported that less than 10 percent of all school bus accidents resulted in death or injury. New York, however, has reported that 60 to 66 percent of all school bus accidents result in death or injury. Assuming that school bus accidents in New York are no more dangerous than those in Maryland, either New York is not reporting noninjury accidents as consistently as is Maryland, or what would be considered minor injuries sustained in school bus accidents in New York is called noninjuries in Maryland—or both. The data in Table A-1 suggest that the severity of school bus accidents differs among the states.

Using data for 1986 from Table A-1, Figure A-1 shows the percentages of school bus accidents that result in death or injury in six states (California, Minnesota, New York, North Carolina, Tennessee, and Texas).

Injury and fatality percentages recorded in New York are more than four times higher than those recorded in Tennessee. However, even if New York data were eliminated from this figure, the difference in percentage of school bus accidents that result in death or injury between the highest and the lowest state would still be more than two to one.

Another difference among the states' school bus accident definitions can be seen from the data in Table A-2. In this table the numbers of school bus

TABLE A-1 PERCENTAGE OF REPORTED SCHOOL BUS-RELATED ACCIDENTS THAT RESULTED IN DEATH OR INJURY

	Year							
State	1980	1981	1982	1983	1984	1985	1986	1987
California	18.1	18.3	20.9	20.2	23.9	22.5	19.8	18.9
Connecticut			22.0	16.0	17.3			
Illinois		18.5	16.8	18.4	17.4	17.0	15.6	
Maryland								9.8
Michigan		24.0	20.6	24.2	23.7	24.5		
Minnesota	[illegible]	23.1	22.2	24.5	26.5	27.0	24.6	
New Jersey	33.7	30.3	29.7	32.1	35.6	33.3		
New York	63.7	65.4	63.6	60.2	61.6	61.6	65.9	
North Carolina		28.7	28.2	29.6	28.8	31.3	32.5	31.5
Pennsylvania			18.3	18.3	18.3	18.3	18.3	
Tennessee	14.1	8.7	12.1	14.6	15.1	14.0	15.2	13.1
Texas	26.9	28.4	29.7	28.5	29.3	30.9	30.7	

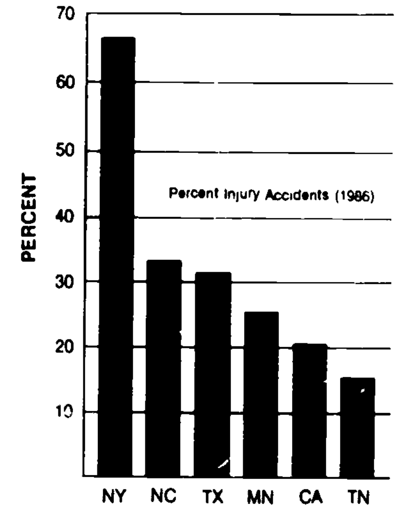

FIGURE A-1 Percentage of school bus accidents that resulted in death or injury in six states.

accidents and school buses involved in accidents are given for Illinois, Michigan, New York, and Texas. In Illinois between 1981 and 1986, 15,012 school bus accidents involving 15,257 school buses were recorded; that is, 1.02 school buses per accident. Because two or more school buses can be involved in an accident, it is possible for a state to record more school buses involved in accidents than school bus accidents.

From 1980 through 1986, 11,876 school bus accidents involving 8,602 school buses were recorded in Texas (i.e., 0.72 school buses per accident). How can Texas record more school bus accidents than school buses involved in accidents? The answer lies in Texas' definition of a school bus accident:[2]

> The state of Texas will code an accident as school bus-related anytime a school bus is involved in an accident, either as a participant or a *non-contact vehicle.* (Emphasis added.)

For Texas school bus accidents in which the school bus is a noncontact vehicle, no information is recorded on the school bus or its driver. Thus, by the preceding definition, Texas reports more school bus–related accidents than school buses involved in accidents. Following a similar practice, Michigan

TABLE A-2 SCHOOL BUS ACCIDENTS AND SCHOOL BUSES INVOLVED IN ACCIDENTS IN SELECTED STATES

	Illinois		Michigan		New York		Texas	
Year	School Bus Accidents	School Buses Involved	School Bus Accidents	School Buses Involved	School Bus Accidents	School Buses Involved	School Bus Accidents	School Buses Involved
1980					1,142	1,157	1,619	1,212
1981	2,162	2,195	1,808	1,518	1,308	1,326	1,689	1,224
1982	2,541	2,584	1,887	1,602	1,449	1,467	1,705	1,261
1983	2,078	2,103	1,356	1,132	1,398	1,416	1,783	1,275
1984	2,466	2,511	1,726	1,455	1,584	1,601	1,689	1,221
1985	2,878	2,925	1,871	1,558	1,478	1,507	1,695	1,228
1986	2,887	2,939	2,134	1,787	1 271	1,295	1,696	1,181
	15,012	15,257	10,782	9,052	9,630	9,769	11,876	8,602
School buses per accident		1.02		0.84		1.01		0.72

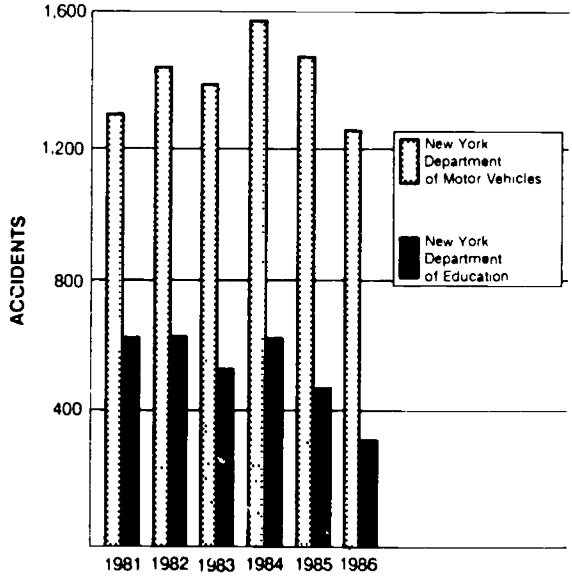

FIGURE A-2 School bus accident data for New York.

also reports more school bus–related accidents than school buses involved in accidents (MDSP 1984). From the data in Table A-2 it can be seen that Michigan and Texas have fairly broad definitions of school bus accidents. Illinois and New York have more restricted definitions.

Not only do the states have different definitions of "school bus accident"; two departments within the same state sometimes have different definitions as shown in Figure A-2. The data for the state of New York were provided by the Department of Motor Vehicles, which reports accidents by calendar year, and the Department of Education, which issues its figures by school year. Notwithstanding the differences in reporting periods, the difference between the two departments' definitions of a school bus accident is substantial.

Although the New York Department of Motor Vehicles and the Department of Education report different numbers of school bus accidents each year, neither department is necessarily incorrect; each department may be reporting the number of school bus accidents each year by its own definitions. If school bus accidents or school bus–related accidents are defined differently in different states—and in different departments within the same state—any attempt to define school bus accidents and the resulting deaths and injuries for the nation is difficult and subject to error.

Analyses of Data From Illinois, Michigan, New York, and Texas

The existing data on school bus accidents are inadequate nationwide; nevertheless, an attempt was made to use the data that were available to better understand where, when, and why school bus accidents do occur.

Data from Illinois, Michigan, New York, and Texas were used because these states operate large school bus fleets and are geographically representative of different parts of the United States. In addition, the information recorded for school bus accidents in each of these four states is similar in format.

Illinois, Michigan, and Texas display similar distributions of accident severity (Table A-3). School bus accidents in New York, as previously indicated, are more likely to result in death or injury.

The first harmful event in most school bus accidents (80 to 85 percent of all accidents) involves collision with another motor vehicle (Table A-4); vehicle overturn is rarely the first harmful event.

School bus accidents occur predominantly on dry road surfaces. Road surfaces covered with snow or ice are reasonably common in Illinois, Michigan, and New York (Table A-5), however.

School bus accidents occur primarily on weekdays and are uniformly distributed from Monday to Friday (Table A-6). As can be seen from the data provided by Illinois, New York, and Texas, school bus accidents commonly occur in the morning and afternoon. School bus accidents in Texas occur earlier in the morning and later in the afternoon than in Illinois and New York (Table A-7).

TABLE A-3 SCHOOL BUS ACCIDENTS BY ACCIDENT SEVERITY IN SELECTED STATES

	State (%)			
Accident Severity	Illinois[a] (N = 15,129)	Michigan[b] (N = 8,648)	New York[c] (N = 9,630)	Texas[c] (N = 11,876)
Fatal	0.2	0.4	0.6	0.6
Injury	17.0	23.0	62.5	28.6
Property damage only	82.8	76.6	36.9	70.8
	100.0	100.0	100.0	100.0

[a]Calendar years 1981–1986.
[b]School years 1980–1981 through 1984–1985.
[c]Calendar years 1980–1986

TABLE A-4 SCHOOL BUS ACCIDENTS BY FIRST HARMFUL EVENT IN SELECTED STATES

First Harmful Event	State (%) Illinois[a] (N = 15,129)	Michigan[b] (N = 8,648)	New York[c] (N = 9,630)	Texas[c] (N = 11,876)
Overturned	0.2	0.6	0.3	1.0
Other noncollision	0.7	0.4	4.3	0.4
Collision with				
Pedestrian	1.1	2.6	3.9	3.1
Motor vehicle in transit	79.1	84.6	84.9	86.1
Parked motor vehicle	16.0	7.4	–[d]	5.5
Railroad train	–[e]	–[e]	–[e]	–[e]
Pedalcyclist	0.4	0.4	1.3	0.3
Animal	0.2	0.9	0.2	0.2
Fixed object	2.1	3.0	4.7	3.2
Other object	0.2	0.1	0.4	0.2
	100.0	100.0	100.0	100.0

[a]Calendar years 1981–1986.
[b]School years 1980–1981 through 1984–1985.
[c]Calendar years 1980–1986.
[d]This code is not used in New York.
[e]Less than 0.1 percent.

TABLE A-5 SCHOOL BUS ACCIDENTS BY ROAD SURFACE CONDITION IN SELECTED STATES

Road Surface Condition	State (%) Illinois (N = 13,297)	Michigan (N = 8,648)	New York (N = 8,936)	Texas (N = 11,876)
Dry	60.6	52.1	59.1	78.7
Wet	20.9	19.8	23.5	19.7
Snow/ice	18.2	27.2	17.0	1.4
Other	0.3	0.9	0.4	0.2
	100.0	100.0	100.0	100.0

TABLE A-6 SCHOOL BUS ACCIDENTS BY DAY OF WEEK IN SELECTED STATES

	State (%)			
Day	Illinois[a] (N = 15,129)	Michigan[b] (N = 3,227)	New York[c] (N = 9,630)	Texas[c] (N = 11,876)
Sunday	2.4	1.6	1.2	0.3
Monday	18.[illegible]	20.1	19.3	19.4
Tuesday	19.8	19.0	20.5	19.6
Wednesday	19.2	19.2	19.6	18.4
Thursday	19.0	19.7	18.1	19.9
Friday	19.4	18.5	19.6	21.0
Saturday	1.7	1.9	1.7	1.4
	100.0	100.0	100.0	100.0

[a]Calendar years 1981–1986
[b]School years 1982–1983 and 1984–1985.
[c]Calendar years 1980–1986.

TABLE A-7 SCHOOL BUS ACCIDENTS BY TIME OF DAY IN SELECTED STATES

	State (%)		
Time	Illinois (N = 15,012)	New York (N = 9,395[a])	Texas (N = 11,876)
6:00 a.m.–6.59 a.m.	1.3	1.2	2.7
7:00 a.m.–7:59 a.m.	14.2	13.1	21.8
8:00 a.m.–8:59 a.m.	19.1	19.0	12.9
9:00 a.m.–9:59 a.m.	6.0	6.2	1.8
10:00 a.m.–10:59 a.m.	2.5	2.8	1.2
11:00 a.m.–11:59 a.m.	3.7	4.0	2.4
12:00 noon–12:59 p.m.	3.8	3.9	2.1
1:00 p.m.–1:59 p.m.	3.6	3.7	1.8
2:00 p.m.–2:59 p.m.	11.1	11.5	7.2
3:00 p.m.–3:59 p.m.	20.8	18.4	23.7
4:00 p.m.–4:59 p.m.	7.8	7.8	17.0
5:00 p.m.–5:59 p.m.	2.4	2.8	2.4
6.00 p.m.–5:59 a.m.	3.7	5.5	3.0
	100.0	100.0	100.0

[a]Of the 9,630 school bus accidents recorded in New York between 1980 and 1986, "time of accident" was "unknown" in 235 cases

Notes

1. Letter from Captain L.F. Rollins, Commander, Commercial and Technical Services Section, California Highway Patrol, Sacramento, Calif., to TRB, January 22, 1988.
2. Letter from James G. Templeton, Manager, of Statistical Services, Texas Department of Public Safety, Austin, Tex., to TRB, October 5, 1987.

References

ABBREVIATIONS

MDOE	Maryland State Department of Education
MDSP	Michigan Department of State Police
NHTSA	National Highway Traffic Safety Administration

MDOE. 1986. *Maryland Public School Bus Accident Report: School Year 1985–86.* Baltimore, Md.

MDSP. 1984. *Michigan School Bus Accidents: School Year 1983–1984.* Lansing, Mich.

NHTSA. 1977. *Report of the Secretary of Transportation to the United States Congress Pursuant to Section 103 of the 1976 Amendments to the National Traffic and Motor Vehicle Safety Act of 1966.* Report DOT-HS-802 191. U.S. Department of Transportation.

APPENDIX B

Fatal School Bus Accident Narratives

This appendix contains brief narratives of fatal school bus accidents in California (school years 1980–1981 through 1985–1986), Michigan (school years 1980–1981 through 1984–1985), and Pennsylvania (school years 1974–1975 through 1985–1986). For Pennsylvania, only those accidents that resulted in pupil fatalities are reported.

California (CHP 1981)

1. A 17-year-old male driver was killed when his motorcycle ran into the left rear of a stopped pickup. The motorcyclist was thrown into the opposing lane of traffic and was struck by a public Type I school bus. Motorcyclist at fault.

2. A 65-year-old male driver was killed when his pickup and trailer jackknifed on the roadway in heavy fog. He was struck by a public Type I school bus. Other driver at fault.

3. A contractor Type I school bus lost its brakes on a downhill grade, struck two other vehicles, and fatally injured an 18-year-old female. Other than driver at fault.

4. A private Type II school bus struck and killed a 10-year-old male bicyclist. Bicyclist at fault.

5. A 39-year-old male driver of a motorcycle was killed when he failed to stop at an intersection controlled by a flashing red light and was struck by a public Type I school bus. Motorcyclist at fault.

6. A 12-year-old male roller-skating in the roadway was struck and killed when he skated through a stop sign directly into the path of a public Type II school bus. Pedestrian (roller skater) at fault.

7. The driver of a pickup truck and his wife and son were killed when the truck crossed the centerline directly into the path of a public Type I school bus. Truck driver at fault.

8. The driver of a dump truck and a 14-year-old student passenger were killed when the truck crossed the centerline directly into the path of a public Type I school bus. Truck driver at fault.

9. A 7-year-old male nonstudent pedestrian ran onto the roadway and kicked the right rear tire of a public Type I school bus. He was then knocked to the pavement where he struck his head and sustained fatal injuries. Pedestrian at fault.

10. The driver of a motorcycle was killed when the driver of a school bus turned left directly into the path of the motorcyclist. School bus driver at fault.

11. The driver of a pickup truck was killed when, for unknown reasons, he passed out at the wheel, lost control of the truck, and crossed the centerline directly into the path of a public Type I school bus. Truck driver at fault.

12. The driver of a car was killed when the vehicle crossed the centerline directly into the path of a public Type I school bus. Driver of car at fault.

13. A 12-year-old male student passenger sustained fatal injuries when a contractor Type I school bus ran into the rear of a tractor trailer that was stalled in the roadway. School bus driver at fault.

14. The driver of a pickup truck and his passenger were killed when a public Type II school bus preparing to make a left turn was hit from behind by a logging truck. The school bus was forced into the opposing lane and was struck by the pickup truck. Logging truck driver at fault.

15. The driver of a motorcycle was killed when he passed a car and ran into the left side of a public Type I school bus making a left turn. Motorcycle driver at fault.

16. An year-old male student pedestrian sustained fatal injuries when struck by a passing vehicle after he was discharged from a public Type I school bus at an unauthorized stop. The student crossed the street without the benefit of red lights or an escort. School bus driver at fault.

17. A 3-year-old male nonstudent pedestrian sustained fatal injuries when he chased a contractor Type I school bus and fell under the wheels. Nonstudent pedestrian at fault.

Michigan (MDSP 1981)

1. September 29, 1980, 8:12 a.m.: a 21-year-old driver was killed when her vehicle was struck by a school bus.

2. October 28, 1980, 7:39 a.m.: a 63-year-old male driver was killed when his vehicle struck a school bus. Cause of accident was disregard of traffic control.

3. January 27, 1981, 3:53 p.m.: a 47-year-old driver was killed when he lost control of his vehicle on a curve and struck a bus head-on.

4. February 2, 1981, 3:15 p.m.: after leaving the bus, an 8-year-old student was standing in front of the bus when it started to move. The left bumper struck the student, pushing him to the pavement. Student fell underneath the bus and was run over.

5. March 5, 1981, 12:12 p.m.: a school bus was northbound when a second vehicle ran a stop sign from the east, striking the bus. The bus swung to the left over a curb and rolled over. The 49-year-old school bus driver was killed.

6. April 14, 1981, 3:15 p.m.: two pedestrians, ages 12 and 13, ran from the east curb to the west curb in front of a school bus. The 12-year-old was killed.

7. May 5, 1981, 11:35 a.m.: a school bus was northbound when a pickup truck coming from the west failed to yield and struck the school bus. Driver of pickup truck was killed.

8. May 26, 1981, 4:22 p.m.: a school bus was traveling east when a pedestrian ran after the school bus, grabbed the radio antenna, lost his footing, and fell under the left rear wheel.

9. September 1, 1981, 10:50 a.m.: a 68-year-old female driver was killed when her vehicle struck the rear of a vehicle waiting for a school bus to take on passengers.

10. February 8, 1982, 6:45 a.m.: a 48-year-old female driver lost control of her vehicle on an icy roadway, crossed the centerline, and was struck by a northbound school bus.

11. February 8, 1982, 2:22 p.m.: a 5-year-old male student exited the school bus and walked around the front and along the driver's side. He dropped something near the rear tires and, as he bent over to pick it up, was struck by the school bus.

12. April 5, 1982, 1:50 p.m.: a 28-year-old male driver's vehicle left the roadway, struck a guardrail, and swerved across the roadway, striking a school bus head-on.

13. April 22, 1982, 8:45 a.m.: a 6-year-old male student exited the school bus and walked around the front of the bus. When in front of the bus, he dropped something and was struck by the school bus as he bent to pick it up.

14. May 21, 1982, 4:00 p.m.: a 26-year-old male driver struck the rear of a disabled bus and then hit the end of a guardrail. (The bus had engine trouble and was parked in roadway with emergency flashers activated.)

15. October 11, 1982, 8:30 a.m.: a 54-year-old female driver was killed when her vehicle went out of control and struck a school bus broadside.

16. October 19, 1982, 7:50 a.m.: an 11-year-old female bicyclist was killed when she fell into the side of a school bus as it passed.

17. October 27, 1982, 4:20 p.m.: a 5-year-old female student was killed as she exited the school bus and ran into the side of a vehicle that was passing the bus.

18. January 13, 1983, 3:13 p.m.: a 12-year-old male student exited the school bus and walked around to the front of the bus. He dropped some papers and, while trying to pick them up, was struck by the bus as it began to depart.

19. May 17, 1983, 12:12 p.m.: a 36-year-old male motorcyclist was killed when he ran into the side of a school bus at an intersection.

20. September 29, 1983, 3:15 p.m.: a 17-year-old passenger on a motorcycle was killed when another vehicle made a left turn in front of him. The school bus, stopped at the intersection, was hit by flying debris.

21. October 11, 1983, 2:29 p.m.: a 38-year-old driver and a 37-year-old passenger were killed when their vehicle made a left turn in front of an approaching school bus.

22. October 18, 1983, 2:05 p.m.: a 61-year-old passenger was killed in a 4-vehicle accident when a school bus rear-ended her vehicle, sending it into the path of two other vehicles.

23. December 15, 1983, 12:53 p.m.: a school bus struck and killed a 5-year-old pedestrian as the bus driver was backing from the driveway where the bus was being turned around.

24. February 2, 1984, 4:30 p.m.: a 32-year-old pedestrian fell against a turning school bus. He died as a result of his injuries 3 days later.

25. February 27, 1984, 4:10 p.m.: an 11-year-old was struck and killed by a vehicle that ran off the roadway as the vehicle attempted to avoid the stopped school bus that had just discharged him.

26. July 12, 1984, 2:13 p.m.: an 85-year-old driver was killed when her vehicle skidded across the roadway and into the path of an oncoming school bus.

27. September 6, 1984, 7:55 a.m.: a 21-year-old driver was killed when a school bus made a left turn into his path.

28. October 24, 1984, 7:46 p.m.: a 65-year-old driver was killed when he ran into the rear of a disabled school bus left in the travel lane of a roadway.

29. November 6, 1984, 4:01 p.m.: a 58-year-old driver was killed when she hit a school bus head-on while attempting to pass a vehicle in her direction of travel.

30. November 14, 1984, 8:03 a.m.: a 48-year-old driver was killed when a school bus failed to yield at an intersection and crossed into her path.

31. December 5, 1984, 12:15 p.m.: a 41-year-old school bus driver was killed when a semitrailer jackknifed into her lane of travel.

32. December 20, 1984, 3:45 p.m.: a 6-year-old was hit by a school bus after being discharged from the bus.

33. January 18, 1985, 12:02 p.m.: a 5-year-old was struck by the school bus that had just discharged her as a passenger.

Pennsylvania (PennDOT 1987)

1. The school bus stopped to discharge passengers at the bus stop. A 5-year-old male student crossed in front of the bus. Someone called out the student's name, and he turned. the driver, not seeing the student, moved forward. The student was struck and killed.

2. The school bus stopped to discharge passengers at the bus stop. A 7-year-old female student exited the school bus. The driver proceeded to make a right turn. The student was struck by the rear wheel of the bus. The driver was unaware that the student was struck and killed.

3. The school bus stopped to discharge passengers at the bus stop. A 6-year-old female student exited the school bus, crossed in front of it, and walked back along the left side. The driver checked to ensure that all students had crossed in front of the bus and proceeded with the run, hitting the student with the left front bumper.

4. A school vehicle (station wagon) made a turn; it then ran off the roadway and collided with a tree. The driver and one 12-year-old male student were killed.

5. The school bus stopped to discharge passengers at the bus stop. A 6-year-old male student exited the school bus. The driver believed that the student was walking to the rear of the bus. but the student had turned and walked around the front. Not seeing the student, the driver moved forward, striking and killing the student.

6. A 10-year-old male student exited the bus, darted across the street in front of the bus, and was struck by a passing school bus. The student was thrown a short distance north of the bus that discharged him.

7. The school bus stopped to discharge passengers at the bus stop. A 10-year-old male student exited the school bus, crossed in front of it, and was struck by a truck that illegally passed the stopped school bus.

8. The school bus stopped to discharge passengers at the bus stop. A 5-year-old female student exited the school bus and crossed in front of it. The driver believed that all students had crossed and proceeded with the run, hitting the student with the left bumper.

9. The school bus stopped to discharge passengers at the bus stop. An 8-year-old male student exited the school bus and crossed in front of it. The student dropped his lunch box and, as he bent to retrieve it, was hit by the left front bumper of the bus.

10. The school bus was loaded with students and departing from the school parking lot. A 15-year-old male student ran toward the bus from the right rear and tripped and fell under the right rear dual wheels. The driver stated that he checked the mirrors and had negotiated a right-hand turn at the time of impact.

11. The school bus stopped to discharge passengers at the bus stop. A 10-year-old male student exited the school bus, crossed in front of it, and was struck in the passing lane by a truck that illegally passed the stopped school bus.

12. The school bus stopped to discharge passengers at the bus stop. As the driver started to pull forward, an 8-year-old male student ran from his driveway for some unknown reason and was struck by the rear wheels of the bus.

13. The school vehicle parked on the opposite side of the roadway to pick up students. An 8-year-old male student crossing the roadway stepped directly into the path of an oncoming truck. The visibility of the truck driver was obstructed by shrubs and trees.

14. The school bus stopped to discharge passengers at the bus stop. The student crossed in front of the bus and stepped onto the curb. As the driver started to pull forward, the student ran into the street and was struck by the bus and crushed by the left rear wheel.

15. The school bus stopped to load a group of students in the school parking lot. Another school bus stopped to discharge a 9-year-old female student who suddenly remembered she had to stay after school. She crossed in front of the bus. As the driver of the first bus proceeded around the second bus, he struck the student.

16. The school bus stopped to discharge passengers at the bus stop. A 5-year-old male student crossed in front of the bus and stopped to pick up some school papers. The driver stated that she checked the mirrors, started to pull forward, and after hearing a thump, stopped the bus. Apparently the boy had been struck by the right rear wheels of the bus.

17. The school bus stopped to discharge passengers at the bus stop. The student crossed in front of the bus, stopping to wave at a passerby. As the driver started to pull forward, he struck the boy, knocking him to the ground with the front end of the bus, and ran over him with the left rear dual wheels.

18. The school bus stopped to discharge passengers at the bus stop. Students crossed in front of the bus to the left side of the road. The driver stated that he checked the mirrors, saw no one, and proceeded to pull out to make a turn and drive to the next stop. Apparently a 13-year-old male student slipped and fell under a rear wheel of the bus.

19. The 13-year-old male student ran out of the school and down the sidewalk to catch the school bus. The sidewalk was covered with ice and very slippery. The student lost his footing and slid in front of the rear dual wheels of the school bus as it was pulling away.

20. The school bus stopped to discharge a group of students in the school parking lot. As the driver started to pull away he felt a thump and stopped. Witnesses stated that the accident was caused by pushing and shoving and that the 14-year-old female student evidently fell under the right rear wheels of the bus.

21. The school bus stopped to discharge passengers at the bus stop. A 6-year-old male student exited the school bus and started to cross the street in front of it. The driver started to drive away and struck the student with the front end of the bus.

22. The school bus stopped to discharge passengers at the bus stop. An 8-year-old female student exited the bus and crossed in front of it. A discipline problem distracted the attention of the driver and he believed that the student had crossed the road. He proceeded with the run and struck the student.

23. The school bus stopped to discharge passengers at the bus stop. A 6-year-old female student exited the bus. The driver believed that all the students were on the sidewalk and proceeded with the run, hitting the student (6-year-old female).

24. The school bus was pulling up to the curb in front of the school to pick up students to transport them home. As the bus was stopping, the students rushed and pushed against the bus door, causing a 6-year-old male student to be pushed beneath the right front wheel. The bus was traveling approximately 1 to 2 mph and traveled a distance of 3 ft after the student was pushed beneath the wheel.

25. The school bus was hit head-on by a tractor trailer truck; the driver and her 9-year-old daughter were killed. There were no other students on the bus.

26. The school bus stopped to discharge passengers at the bus stop. A female student (age unknown) exited the school bus and crossed in front of it. The driver believed that all students had crossed and proceeded with the run, striking the student.

27. A school vehicle (unmarked van) collided with the back of a flatbed truck; a 15-year-old male student was killed. It was noted that no seat belts had been used.

28. The school bus was passing a 12-year-old female student's driveway en route to the bus stop. The student was waiting in the driveway for another bus and darted in the street in front of the bus and was struck. The student's visibility was blocked by her father's van, which was parked in the driveway.

29. The school bus stopped to discharge passengers at the bus stop. A 5-year-old male student exited the bus, walked along the side to the rear of the bus, then turned around and walked to the front of the bus and crossed in front of it. Believing the student had crossed behind the bus, the driver proceeded with the run and struck the student.

30. The school bus stopped to discharge passengers at the bus stop. A 7-year-old male student exited the bus, waited to cross behind it, and slipped and fell into the rear of it. The student was not struck by the bus.

31. The school bus stopped at the top of an icy hill while the driver checked the road condition. The driver instructed the students to exit the bus and stand off the roadway while he checked the road condition. A pickup truck slid out of control and ran into the group of students, killing a 9- or 10-year-old male student.

32. The school bus stopped to discharge passengers at the bus stop. A 7-year-old male student exited the bus, crossed in front of it, and was struck by a car illegally passing the stopped school bus. The driver of the car believed that the red flashing lights meant that the bus was disabled.

References

ABBREVIATIONS

CHP	California Highway Patrol
MDSP	Michigan Department of State Police
PennDOT	Pennsylvania Department of Transportation

CHP. 1981 (and later editions). *Information Bulletin: Summary of School Bus Accidents 1980/81*. Sacramento, Calif.

MDSP. 1981 (and later editions). *Michigan School Bus Accidents: School Year 1980–1981*. Lansing, Mich.

PennDOT. 1987. *School Bus Accident Report, 1985–1986*. Harrisburg, Pa.

APPENDIX C

Supplemental Information on the 26 Fatal School Bus Accidents That Resulted in Passenger Deaths

Analyses of 26 fatal school bus accidents (1982–1986) that resulted in the deaths of school bus passengers are presented in Chapter 3. Additional information on the accidents was provided by the National Transportation Safety Board (NTSB), state and local police departments, state directors of pupil transportation services, and private accident investigators and is presented in this appendix. Although this information is useful in characterizing the nature of fatal school bus accidents and suggests the effectiveness of some safety measures, it is often not possible to make conclusive judgments about whether particular fatalities could have been avoided if a specific safety measure had been used. Even with intensive post-crash investigation, such judgments are difficult and subject to error.

It should be noted that two of the school bus accident reports taken from the Fatal Accident Reporting System (FARS) files were miscoded. The school bus in Case 12 was used to transport retarded adult citizens. The bus was painted blue and was not equipped with standar school bus safety features such as flashing red signal lights or stop signal arms. The school bus in Case 23 was an intercity bus used to transport students, typically adult students, to and from the Ozark Bible Institute.

In another accident (Case 2), a school bus passenger exited the rear emergency door of a school bus and was struck by a truck in the opposing travel lane. Three other school bus passengers in Cases 5, 17, and 18 were killed when they fell or jumped from moving school buses.

All 26 of the school bus accidents reported in this appendix occurred between 1982 and 1985. No school bus accidents that resulted in the deaths of school bus passengers were recorded in the United States in 1986.

1. January 25, 1982 (Texas Department of Public Safety Accident Report 2026774). A 1975, Type I school bus was traveling south on a county road. Due to apparent brake failure, the bus ran through a "T" intersection, jumped a bar ditch, and came to rest in a plowed field. The bus did not overturn. Photographic evidence suggests that external damage to the bus was not extensive (Figure C-1).

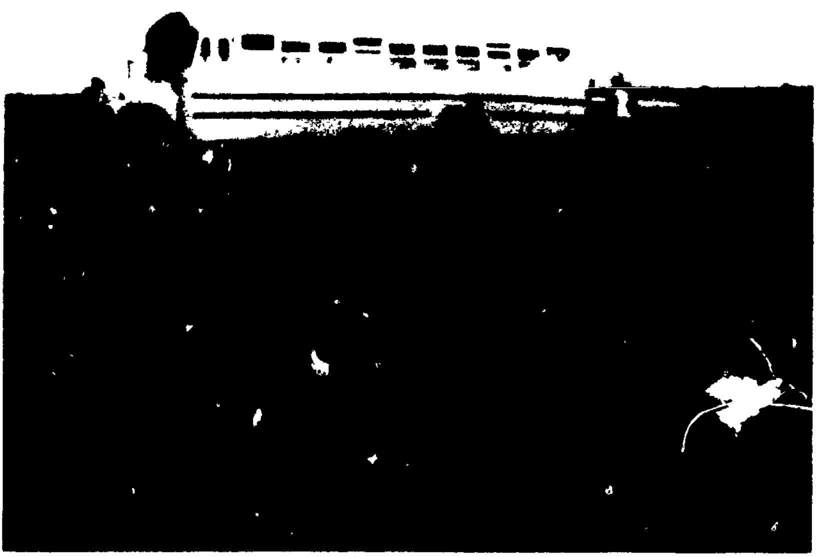

FIGURE C-1 A 1975, Type I school bus ran through intersection, jumped a bar ditch, and came to rest in a plowed field. *Photograph courtesy* James Wright, Corpus Christi Independent School District.

A 7-year-old male passenger died from injuries suffered inside the bus during the accident; he was not ejected from the bus. The bus driver and seven passengers received nonincapacitating (B-level) injuries; four passengers received incapacitating (A-level) injuries.

2. February 15, 1982 (Alorton, Illinois Police Accident Report 7869014). A Type I school bus (date of manufacture unknown) was westbound on a two-lane road. The school bus driver reported hearing a buzzer that indicated the rear emergency door was open. The driver stopped the bus. A 14-year-old girl who exited the bus through the rear emergency door was apparently struck and killed by an eastbound truck.

3. February 20, 1982 (Missouri State Highway Patrol Traffic Accident Report 60651). A 1981, Type I school bus was westbound on an Interstate highway (Figure C-2). "Accident apparently occurred when driver . . . ran off right side of roadway, down an embankment, skidded on right side down a concrete drainage ditch and struck a concrete abutment." A 59-year-old female passenger who was not ejected was killed. The driver and 14 other passengers received disabling injuries. One passenger received an evident (nondisabling) injury. The remaining 26 passengers were not injured.

4. March 25, 1982 (Louisiana Department of Public Safety State Computer 0161279). A 1978, Type I school bus headed south had stopped at an intersection of a two-lane state highway. On entering the intersection, the bus was struck on the right side by an eastbound tractor semitrailer. Thirty of the 51 students on board the bus were injured; an 8-year-old male was killed.

5. June 4, 1982 [North Carolina Traffic Accident Report (Caldwell County)]. Memorandum from Wilbur F. Woodall, Jr., North Carolina Division of Motor Vehicles, to Worth McDonald, June 8, 1982.

"On Friday, June 4, 1982, bus #85 (1974 Ford) was traveling south on RP 1001. This area of the county had been experiencing heavy rain all afternoon, and [it] was raining at the time of the accident. There were only four passengers on the bus at the time of the accident.

"The driver of the bus . . . asked one of the passengers . . . to wipe the right side of the windshield which was fogging up during the heavy rain. After cleaning the windshield . . . [the student] . . . stayed in front of the bars with his back against the front door.

"Another student . . . was sitting on the front seat and accidentally hit the door safety latch. As the door opened . . . [the student] . . . fell out and was caught on a metal spike underneath the bus." The student, a 15-year-old male, was struck and killed by the rear wheels of the bus.

6. June 17, 1982 (Georgia Department of Public Safety Accident Report 21-113-82). A 1978, Type I school bus carrying 66 passengers was eastbound on a county dirt road. The bus stopped at a stop sign and then entered an intersection, where it was struck on the right side by a northbound truck

FIGURE C-2 A 1981, Type I school bus ran off roadway, skidded on right side down a concrete drainage ditch, and struck a concrete abutment. *Photographs courtesy* Judy Bellinger, Missouri Department of Elementary and Secondary Education.

traveling an estimated speed of 40 to 45 mph. A 9-year-old male in the second-row, right-side, window seat was killed.

7. October 8, 1982 (Texas Department of Public Safety Accident Report 2342877). A 1977, Type I school bus was southbound in the right lane on a six-lane, divided Interstate highway. A southbound passenger car traveling in the middle lane at high speed struck the bus on the left side. The school bus swerved to the left, went through a guardrail and across a body of water in the median, and overturned on its left side after striking a second median guardrail that protected the northbound lanes. A 14-year-old female passenger in the bus was killed. Five other passengers sustained incapacitating injuries, and 15 sustained nonincapacitating injuries.

8. December 8, 1982 (Georgia Department of Public Safety Accident Report 6-315-82). A 1982, Type I bus northbound on a two-lane state highway was preparing to stop to unload passengers. The driver of a southbound passenger car, upon seeing the stopping school bus, braked and skidded. The passenger car was struck from the rear by a tractor semitrailer, which jackknifed and struck the school bus in the front and along the left front side. The school bus rotated to the right and turned over on its right side. A 6-year-old female seated in the front row on the right side of the bus was killed.

9. February 24, 1983 (NTSB 1983a, 17). A 1972, Type I school bus was southbound on a two-lane state highway. A northbound dump truck crossed the centerline and struck the school bus head-on. A female school bus passenger seated in the row behind the driver was killed. "In this accident, at least 18 passengers sustained Abbreviated Injury Scale (AIS) Level 1 (minor) and 2 (moderate) injuries to the head and facial areas. Blood transfers were noted on the exposed metal seatbacks and seatframes."

10. March 9, 1983 (Texas Department of Public Safety Accident Report 3110025). A tractor semitrailer was southbound on a four-lane road that had a posted speed limit of 40 mph. The tractor semitrailer jackknifed on a wet surface and crossed the centerline, striking a passenger car in the left rear. The tractor semitrailer continued across the northbound lanes and struck a northbound 1978, Type I school bus nearly head-on. A 14-year-old female school bus passenger was killed.

11. March 25, 1983 (NTSB 1983b). A 1975, Type I school bus was used to transport 31 high school students and 6 teachers on a school-sponsored outing. At 5:40 a.m., the bus rounded a horizontal curve at too great a speed, slid into the opposing lane, and proceeded across a stop-controlled "T" intersection. On the other side of the intersecting road, the bus overturned in a drainage ditch. The driver, four teachers, and four students were killed. The remaining 29 passengers (2 teachers and 27 students) received varying levels of injury.

12. April 5, 1983 (NTSB 1984a) (New York State Police Accident Report 3-214430). A 1982, Type I bus *painted blue* and operated by the New York

State Association for Retarded Children (NYSARC) was involved in a head-on accident with a 2-ton flatbed truck. The bus driver and four adult passengers (ages 34, 56, 24, and 39) were killed. "The NYSARC had sought to order the bus with flashing red lights and to have it painted schoolbus chrome yellow with black trim for added safety, but the request was denied by the New York State Department of Transportation (NYSDOT) on the grounds that the passengers were not children and the vehicle was not to be used for school transportation purposes" (NTSB 1984a, 12). In denying the request to have the bus painted yellow, the NYSDOT cited Federal Highway Safety Program Standard 17, which prohibits buses from being painted yellow and marked as school buses if they are not used for school transportation.

This accident was erroneously coded in FARS as a school bus accident. "[I]t was determined that the accident of April 5, 1983 (3-214430) was not a school vehicle accident."[1]

13. January 10, 1984 (NTSB 1984b). A 1979, Type I school bus was westbound on a two-lane state highway that had a speed limit of 50 mph. The bus was struck on the left front by a tractor semitrailer that crossed the centerline as the result of a previous collision. The bus overturned and came to rest on its roof, off the road (Figure C-3). The bus driver and a 5-year-old male sitting in the front-row, window seat behind the driver were killed. Twelve other students passengers were injured; two were not injured.

14. January 21, 1984 (NTSB 1984c). A 1977, Type I school bus (manufactured before April 1, 1977), returning from a school-sponsored outing, was westbound on a two-lane highway when it struck an eastbound tank truck (a tractor-semitrailer-full trailer) that had jackknifed and crossed into the westbound lane. The truck was stationary at the time of the collision, which occurred at 6:18 p.m.

On impact a fire started in the engine compartment and stairwell of the bus, apparently from aviation fuel carried by the tank truck. The school bus driver and eight passengers (all seated in the first two rows of the bus) were killed. All nine vehicle occupants apparently died of mechanical trauma, not fire or smoke inhalation. The remaining 18 passengers sustained various levels of injuries.

15. May 9, 1984 (NTSB 1984d). A 1977, Type I school bus (manufactured before April 1, 1977) had stopped (with red flashing lights activated) on a two-lane highway to unload students. A tractor pulling a flatbed semitrailer approached the stopped bus from the rear at 45 to 55 mph and attempted to pass. A corn planter positioned on the flatbed and extending 4 ft beyond the right edge struck the bus in the left rear and sliced into the occupant compartment. Two children were decapitated and two others died of head injuries.

FIGURE C-3 A 1979, Type I school bus struck on the left front by a tractor semitrailer. *Photograph courtesy* Rehoboth Police Department, Massachusetts.

16. September 27, 1984 (NTSB 1985a). A westbound 1968, Type I school bus with four passengers on board stalled on a railroad track at a grade crossing. On the approach of a northbound train, two students fled the bus. The other two were killed when the bus was struck in the left side by the oncoming train. Both passengers and the driver, who was seriously injured, were ejected.

17. October 25, 1984 (Florida Traffic Accident Report 035569623). A 1977, Type I school bus (month of manufacture unknown) was southbound on Timberlane Road. Occupant (an 11-year-old male student) for unknown reasons released the latch on the emergency door at the rear of the bus and leaped onto the pavement, striking his head. He died the following day.

18. January 25, 1985 (New Mexico State Police Accident Report 563284). A 1977, Type I school bus (month of manufacture unknown) had stalled on a forest road as a result of an electrical malfunction. The driver removed the key from the ignition and went to a nearby residence to call for assistance, leaving the children on the bus. While the driver was away, the bus began rolling down a slight grade. Several children then jumped from the moving bus. One child, a 7-year-old girl, died when she was struck by the moving bus.

19. April 22, 1985 (Minnesota Department of Public Safety Accident Report 51120001). A 1984, Type I school bus had just stopped at a stop-controlled intersection. As the westbound bus pulled into the intersection, it was struck on the right side by a southbound tractor semitrailer carrying a load of lumber. The bus overturned, and a 15-year-old female passenger was killed (Figure C-4). Six other children were injured.

20. April 29, 1985 (NTSB 1985b). A 1977, Type I school bus (manufactured after April 1, 1977) stopped on a two-lane highway with warning lights flashing to unload passengers. The bus was struck from the rear by a tractor semitrailer hauling 99 head of cattle and traveling at an estimated speed of 59 mph (Figure C-5). Two of the 32 school bus passengers were killed; 26 others sustained minor to serious injuries.

21. May 31, 1985 (NTSB 1986). A 1982, Type I school bus was traveling south at 32 mph on a two-lane highway on the outside of a horizontal curve. A northbound tractor semitrailer struck the bus on the left side near the front. The "skin" of the bus was torn open and passengers in the first three rows of seats behind the driver were ejected. Six passengers were killed and 22 were injured.

22. June 7, 1985 (CHP 1985). A Type I school bus (date of manufacture unknown) traveling at approximately 45 mph was southbound on an Interstate

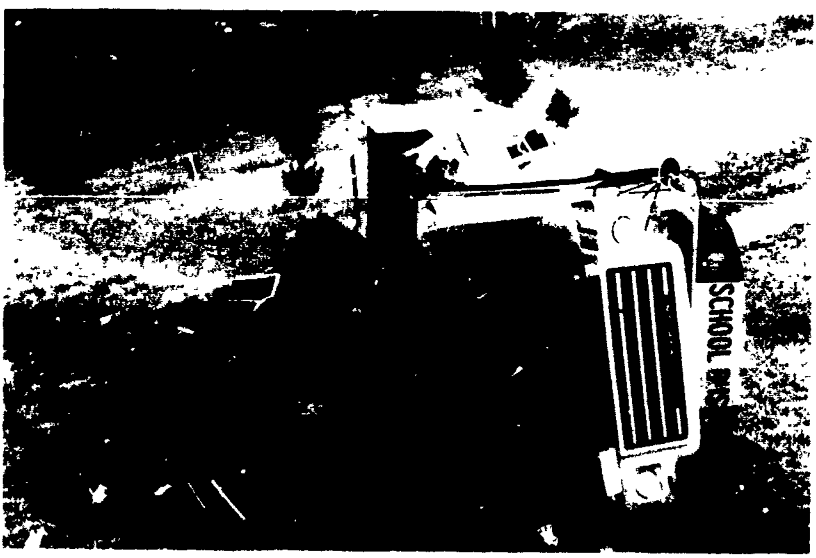

FIGURE C-4 A 1984, Type I school bus struck on the right side by a tractor semitrailer loaded with lumber. *Photograph courtesy* Minnesota Department of Education.

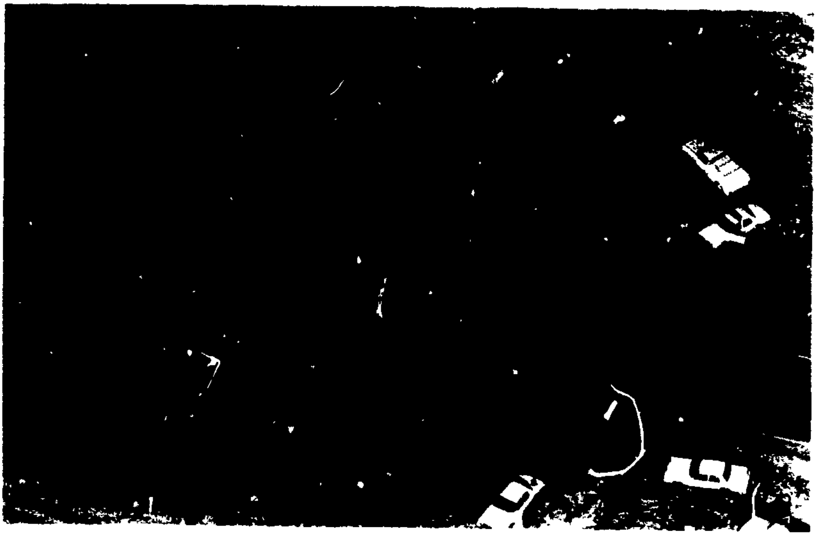

FIGURE C-5 A 1977, Type I school bus struck from the rear by a tractor semitrailer traveling approximately 59 mph. *Photograph courtesy* Brian Winters, *Arizona Daily Sun.*

highway when it struck a tractor semitrailer that had stalled in the right lane. The emergency flashers on the stalled truck had been activated. The school bus was transporting more than 70 sixth grade students and their chaperons to a school-sponsored activity. The accident occurred at approximately 10:20 a.m. Traffic was relatively light and visibility was good.

The accident may have resulted from driver inattention: "He was apparently reading directions on a note, which was on his seat under his right leg" (Kinney 1988).

23. September 13, 1985 (NTSB 1987a). This accident was erroneously coded in FARS as a fatal school bus accident. The bus in question was a ". . . 1965 General Motors Corporation (GMC) Model PD-4106, 2-axle, intercity coach. . . ." (NTSB 1987a, 13). The passengers were aged 17 to 66 and were students at the Ozark Bible Institute.

In this accident the bus overturned; nine passengers were ejected and four were killed.

24. October 10, 1985 (New York State Police Accident Report 5-546268). The driver of a 1978, Type I school bus lost control of the vehicle on a two-lane road while traveling at a speed of approximately 15 to 20 mph. The bus ran down a sloped embankment on the left side of the road, came back across the road, and ran down the right-side embankment before coming to a stop.

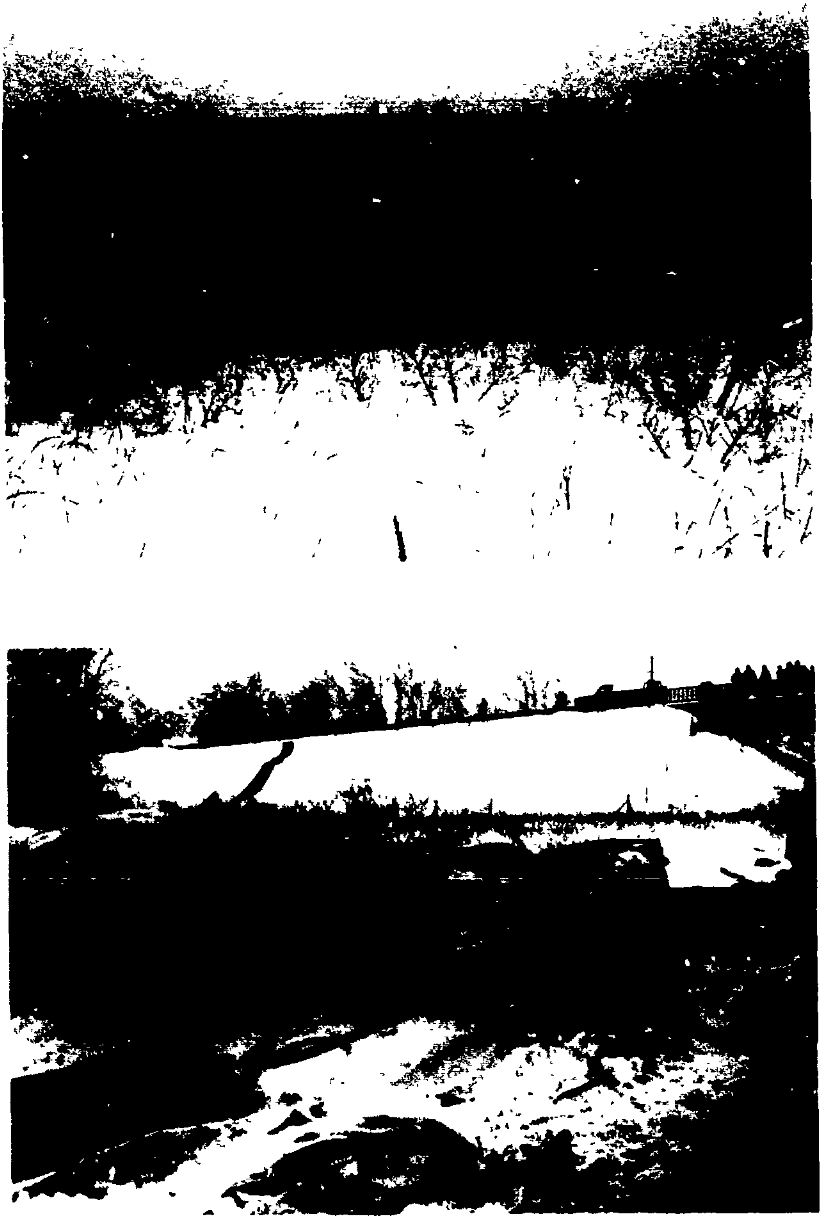

FIGURE C-6 A 1974, Type I school bus struck from the rear by a tractor semitrailer and knocked into a guardrail and bridge piers before it overturned. *Photographs courtesy* Michigan Department of State Police.

Damage to the bus was relatively minor. Of the 15 passengers on board, 9 escaped injury, 5 received minor injuries, and 1 was killed.

> [I]n sharp contrast to the rest of the occupants, one boy received a fatal liver injury (severely lacerated liver). However, according to the pathologist, the boy was at higher risk to this type injury than other children because his liver was not a normal, healthy liver; the boy had an enlarged liver situated lower in the abdomen than normal. It is believed that during the accident sequence, this child who initially was not seated, was leaning over the seat back in front of him, and when the rear wheels bounced over the embankment, the seat back was accelerated sharply into the child's torso and inflicted the fatal injury. (NTSB 1987b, 103)

25. November 11, 1985 (NTSB 1987c). A 1979, Type I school bus was traveling at an estimated speed of 75 mph on an Interstate highway when the driver lost control, striking a guardrail and the concrete base to a sign support. During the collision, the bus body and chassis separated. Two of the 13 passengers on board were killed.

26. December 5, 1985 (Michigan Department of State Police Complaint 51-3403-85). A 1974, Type I school bus was traveling at about 40 mph east in the right lane of an Interstate highway. The bus was struck from behind by a tractor semitrailer and knocked into a guardrail and bridge piers; it then overturned (Figure C-6). The outer body panels were torn apart, leaving a gaping hole in the right side and roof of the bus. Four of the 23 passengers were killed and 17 others were injured.

Note

1. Letter from H. Shufon, Chief Clerk, Accident Records Bureau, State of New York Department of Motor Vehicles, Albany, New York, to TRB, August 16, 1988.

References

ABBREVIATIONS

CHP	California Highway Patrol
NTSB	National Transportation Safety Board

CHP. 1985. *Information Bulletin: Summary of School Bus Accident Statistics, Fiscal Year 1984/85*. Sacramento, Calif.

Kinney, R. 1988. Summary report of the June 7, 1985, accident made available to the committee on September 7, 1988, by Ron Kinney, Supervisor of School Transportation for the California Department of Education.

NTSB. 1983a. *Highway Accident Report—Collision of Humboldt County Dump Truck and Klamath-Trinity Unified District Schoolbus, State Route 96 near Willow Creek, California, Feb. 24, 1983*. Report NTSB/HAR-83/05. Washington, D.C.

NTSB. 1983b. *Highway Accident Report—Jonesboro School District Schoolbus Run-Off-Road and Overturn, State Highway 214 and State Highway 18, near Newport, Arkansas, March 25, 1983*. Report NTSB/HAR-83/3. Washington, D.C.

NTSB. 1984a. *Highway Accident Report—Valley Supply Co. Truck Towing Farm Plow/Anchor Motor Freight Inc. Car Carrier Truck/New York State Assoc. for Retarded Children Bus, Collision and Fire, State Route 8, near Holmesville, N.Y., April 5, 1983*. Report NTSB/HAR-84/01. Washington, D.C.

NTSB. 1984b. *Highway Accident Report—Collision of G&D Auto Sales, Inc., Tow Truck Towing Automobile, Branch Motor Express, Company Tractor-Semitrailer, Town of Rehoboth Schoolbus, Rehoboth, Massachusetts, January 13, 1984*. Report NTSB/HAR-84/05. Washington, D.C.

NTSB. 1984c. *Schoolbus/Truck Collision US2, Essex, Montana*. Report MKC84-M-SB18. Washington, D.C.

NTSB. 1984d. *Factual Report of Investigation Rochester, Missouri Rear-End Collision*. Report MKC84-H-SB25. Washington, D.C.

NTSB. 1985a. *Railroad/Highway Accident Report—Grade Crossing Collision of a Florida East Coast Railway Company Freight Train and an Indian River Academy Schoolbus, Port St. Lucie, Florida, September 27, 1984*. Report NTSB/RHR-85/01. Washington, D.C.

NTSB. 1985b. *Highway Accident Report—Collision of Tuba City School District School Bus and Bell Creek, Inc. Tractor-Semitrailer, US 160 near Tuba City, Arizona, April 29, 1985*. Report NTSB/HAR-85/06. Washington, D.C.

NTSB. 1986. *Highway Accident Report—Multiple Vehicle Collision and Fire, U.S. 13 Near Snow Hill, North Carolina, May 31, 1985*. Report NTSB/HAR-86/02. Washington, D.C.

NTSB. 1987a. *Highway Accident/Incident Summary Report—near Ackerly, Texas, July 20, 1985; Eureka Springs, Arkansas, September 13, 1985; and Bramwell, West Virginia, October 13, 1985*. Report NTSB/HAR-87/01/SUM. Washington, D.C.

NTSB. 1987b. *Safety Study—Crashworthiness of Large Poststandard Schoolbuses*. Report NTSB/SS-87/01. Washington, D.C.

NTSB. 1987c. *Schoolbus-Loss of Control and Collision with Guardrail and Sign Pillar, U.S. Highway 70 near Lucas and Hunt Road, St. Louis County, Missouri, November 11, 1985*. Report NTSB/HAR-87/02. Washington, D.C.

APPENDIX D

Thirteen School Bus Accidents in Texas That Resulted in Passenger Deaths

In a study conducted at the Texas Transportation Institute an attempt was made to determine if and the degree to which seat belts (lap belts) would have prevented the deaths of 19 school bus passengers killed in accidents that occurred between 1975 and 1984 (Hatfield and Womack 1986). This assessment was made from information contained in the police reports of the 13 accidents in which the 19 passengers were killed.

The 13 police officer narratives reviewed by Hatfield and Womack (1986), along with other relevant information taken from the accident report forms, are presented in this appendix.

1. *Accident narrative*: Vehicle was traveling east on Old Elgin Highway with the back door of the bus open. Vehicle was going around a curve when a 6-year-old boy sitting on the second step of the bus fell out and was struck by the bus.

Passenger fatalities: One (male, 6 years old).

Type of injury: Head.

2. *Accident narrative*: Vehicle was driving on shoulder while turning right onto another city street. Vehicle struck fire hydrant and telephone pole.

Passenger's head was out of the window and struck telephone pole. Passenger was in the fifth seat on right side of bus.

Passenger fatalities: One (male, 14 years old).

Type of injury: Head.

3. *Accident narrative*: Vehicle 2 [8- to 10-ton truck with a fluorescent orange triangle (slow-moving vehicle) properly displayed] was northbound on Loop 289. Vehicle 1 (school bus), also northbound on Loop 289, struck Vehicle 2 in the rear.

Passenger fatalities: One (male, 7 years old).

Type of injury: Multiple (passenger ejected through windshield).

4. *Accident narrative*: Vehicle 1 (Ford half-ton pickup) was traveling southbound on SH 24 when it collided with Vehicle 2 (school bus) traveling northbound. The collision knocked the rear wheels of the school bus loose, causing the bus to skid sideways, run off the road, and overturn.

Passenger fatalities: One (female, 16 years old).

Type of injury: Broken neck (passenger thrown around inside bus).

5. *Accident narrative*: Vehicle 1 (school bus) was traveling west on US 180. Vehicle 2 (International Cargostar truck) was traveling south on FM 611 approaching the intersection with US 180. Approximately 100 ft from the intersection, Vehicle 2 passed a southbound vehicle that was slowing to stop at the intersection. Vehicle 2 continued south in left lane of traffic, ran through stop sign and flashing red light, and struck Vehicle 1 in right side. Vehicle 1 was knocked into ditch on south side of US 180, and came to rest on its top.

Passenger fatalities: Five (female, 17 years old; male, 15 years old; female, 17 years old; female, 14 years old; female, 16 years old).

Type of injury: Multiple, multiple (ejected), multiple, multiple, head.

6. *Accident narrative*: Vehicle 1 (school bus) was parked southbound along the west curb of the street. The vehicle started south and at the same time turned eastward to pass another vehicle parked in front of it along the west curb. The turn to the left (east) caused the right rear of Vehicle 1 to angle to the west, scraping the right back quarter along a utility pole 7 in. west of the west curb. A passenger sitting in the right rear of the vehicle had her head sticking out of the window and was caught between the pole and the bus, breaking her neck in the impact.

Passenger fatalities: One (female, 16 years old).

Type of injury: Broken neck.

7. *Accident narrative*: Vehicle 1 (school bus) was heading east on US 180 at approximately 35 mph. Driver began to accelerate for long upgrade. Vehicle began to slide on icy pavement in a counterclockwise direction, going off the road on the north side and turning onto its right side.

Passenger fatalities: One (male, 8 years old).

Type of injury: Unknown (passenger ejected).

8. *Accident narrative*: Vehicle 1 (school bus) stopped to load students while parked behind another vehicle. Vehicle 1 attempted to pull onto US 83 by turning sharply left, causing rear portion of bus to swing right (passenger was leaning out of rear window), catching passenger's head between vehicle and utility pole.

Passenger fatalities: One (male, 6 years old).

Type of injury: Head.

9. *Accident narrative*: Two bus drivers were changing position while the bus was in motion. Just as the second driver sat down behind the wheel, the vehicle went off the right paved shoulder. In attempting to regain the pavement, the driver overcorrected and the bus swerved to the left into a ditch, hit a bank of dirt, rolled over on its left side, and struck a parked road construction machine.

Passenger fatalities: Three (female, 18 years old; female, 15 years old; female, 15 years old).

Type of injury: Head, multiple internal, head.

10. *Accident narrative*: Driver of Vehicle 1 (school bus) stated that he was driving east, heard a noise, looked back, and saw a passenger lying on the floor of the bus, still in his wheelchair, which had turned over.

Passenger fatalities: One (male, 11 years old).

Type of injury: Head.

11. *Accident narrative*: Vehicle was traveling south on County Road 85A. According to the driver and passengers, the bus experienced apparent brake failure. At the intersection of 85A and County Road 100 (a "T" intersection) the bus traveled across County Road 100 and was airborne 24 ft. The rear wheels struck the south side of the ditch, and the bus traveled another 37 ft before stopping in a plowed field.

Passenger fatalities: One (male, 7 years old).

Type of injury: Multiple (passenger not ejected, but hit roof of bus).

12. *Accident narrative*: Both vehicles were southbound on I-45. Unit 1 (school bus) was in the right lane; Unit 2 (1978 Trans-Am) was in the middle lane. At a high rate of speed Unit 2 hit Unit 1 in the middle and in the left rear, causing Unit 1 to turn left across traffic. Both vehicles headed toward railing and went through. Unit 2 hit the opposite (northbound) railing and fell into the water. Unit 1 followed, hit the railing, and fell on its left side. (According to the collision diagram, there was a 30-ft drop in elevation from the southbound to the northbound lanes.)

Passenger fatalities: One (female, 14 years old).

Type of injury: Head (passenger ejection unknown).

13. *Accident narrative*: Vehicle 1 (truck-trailer rig) was heading south on Almeda when its brakes were applied for traffic. Vehicle 1 jackknifed and went left of the center lane where it struck Vehicle 2 (1975 Dodge passenger

car) heading north on Almeda. The front of the trailer then struck the front of Vehicle 3 (school bus) also heading north.

Passenger fatalities: One (female, 12 years old).

Type of injury: Multiple.

Reference

Hatfield, N. J., and K. N. Womack. 1986. *Safety Belts on School Buses: The Texas Experience*. Report TARE-72. Texas Transportation Institute, The Texas A&M University System, College Station.

APPENDIX E

Cost-Effectiveness Analysis of School Bus Safety Measures

Nine school bus safety measures are analyzed to determine how many lives could be saved and how many injuries could be reduced in an average year at an annual cost of $1 million. The safety measures reviewed are

1. Seat belts,
2. Higher seat backs,
3. School bus monitors,
4. Crossing control arms,
5. Electronic sensors,
6. Mechanical sensors,
7. Stop signal arms,
8. External loud speaker systems, and
9. Pupil education programs.

Each measure was analyzed by using a set of questions, assumptions, and equations. The benefits (i.e., the reduction in deaths and injuries) associated with each safety measure reviewed were calculated from upper limits of the committee's effectiveness estimates.

Two of the safety measures (school bus monitors and pupil education programs) require no capital costs and involve only annual operational costs. The other seven safety measures (which are school bus equipment), require initial capital cost as well as annual operational and maintenance costs. To amortize the capital costs, a service life of 15 years was assumed for each of these seven devices, with no salvage value at the end of that time. The discount rate was set at 5 percent per year. Initial costs and annual maintenance and operational costs varied for each device.

The cost-effectiveness analyses performed were in constant dollars, not current dollars. Had the analyses been performed in current dollars, a higher discount rate would have been used. By using this procedure, it was assumed that the inflationary pressures on the costs of the safety measures analyzed were comparable.

The sensitivity of these analyses to the rate chosen to discount future costs is given in Table E-1. In this table, five discount rates are used to calculate the benefits (i.e., the reductions in fatalities and A-, B-, and C-level injuries) that might be realized by investing $1 million in each of the nine school bus safety measures. As the discount rate is increased from 1 to 20 percent, the benefits associated with each of the seven measures that involve an initial capital cost decrease, but the *relative worth* of each of the seven investments remains essentially unchanged. However, the benefits of the two safety measures that have no capital costs (school bus monitors and pupil education programs) are constant. Therefore, the relative worth of these two safety measures, when compared with the seven measures that have discounted future costs, is affected by the discount rate chosen for these analyses; as the discount rate increases, the relative worth of safety measures without capital costs increases.

Seat Belts

Questions

1. How many school buses (X) could be equipped and maintained with seat belts for an investment of $1 million/year?
2. How many lives would be saved (Y) and how many injuries would be reduced each year by this investment?

Assumptions

1. Of the 390,000 school buses in the United States, 85 percent (331,500) have gross vehicle weight ratings (GVWRs) greater than 10,000 lb and are not equipped with seat belts (S = 331,500).

TABLE E-1 SENSITIVITY TO DISCOUNT RATE OF INJURY REDUCTIONS FOR $1 MILLION ANNUAL INVESTMENT

Safety Measure	Injury Severity	Discount Rate				
		0.01	0.05	0.1	0.15	0.2
Seat belts	Fatalities	0.029	0.023	0.018	0.015	0.012
	A injuries	1.372	1.117	0.878	0.709	0.586
	B injuries	6.862	5.580	4.391	3.542	2.927
	C injuries	19.215	15.626	12.295	9.916	8.197
Higher seat backs	Fatalities	0.569	0.426	0.312	0.240	0.192
	A injuries	22.516	16.856	12.352	9.496	7.592
	B injuries	112.579	84.280	61.759	47.479	37.963
	C injuries	315.222	235.982	172.925	132.941	106.297
School bus monitors	Fatalities	0.020	0.020	0.020	0.020	0.020
	A Injuries	0.252	0.252	0.252	0.252	0.252
	B Injuries	1.036	1.036	1.036	1.036	1.036
	C Injuries	2.791	2.791	2.791	2.791	2.791
Crossing control arms	Fatalities	0.298	0.261	0.222	0.189	0.163
	A injuries	0.688	0.604	0.512	0.437	0.378
	B injuries	1.062	0.931	0.789	0.674	0.582
	C injuries	1.769	1.551	1.315	1.123	0.970
Electronic sensors	Fatalities	0.157	0.131	0.106	0.087	0.073
	A injuries	0.374	0.312	0.252	0.206	0.173
	B injuries	0.558	0.465	0.376	0.309	0.258
	C injuries	0.925	0.772	0.623	0.511	0.429
Mechanical sensors	Fatalities	0.110	0.092	0.074	0.061	0.051
	A injuries	0.261	0.218	0.176	0.144	0.121
	B injuries	0.388	0.324	0.262	0.215	0.180
	C injuries	0.644	0.537	0.434	0.346	0.299
Stop signal arms	Fatalities	0.358	0.299	0.241	0.198	0.166
	A injuries	3.293	2.748	2.216	1.820	1.524
	B injuries	5.011	4.181	3.371	2.768	2.319
	C injuries	8.231	6.869	5.539	4.549	3.810
External loud speaker systems	Fatalities	0.252	0.210	0.170	0.139	0.117
	A injuries	2.205	1.840	1.483	1.219	1.020
	B injuries	3.317	2.768	2.232	1.833	1.535
	C injuries	5.501	4.590	3.701	3.039	2.545
Pupil education programs	Fatalities	0.459	0.459	0.459	0.459	0.459
	A Injuries	2.059	2.059	2.059	2.059	2.059
	B Injuries	3.096	3.096	3.096	3.096	3.096
	C Injuries	5.140	5.140	5.140	5.140	5.140

2. On average, 10 passengers are killed riding in these 331,500 buses each year ($F = 10$). Another 475 receive incapacitating (A-level) injuries ($A = 475$), 2,375 receive nonincapacitating (B-level) injuries ($B = 2{,}375$), and 6,650 receive possible (C-level) injuries ($C = 6{,}650$).

3. If seat belts were installed on school buses, one-half the passengers would use them ($U = 0.50$).

4. If an accident occurs, the use of a seat belt will reduce the likelihood of death and injury by up to 20 percent ($R = 0.20$).

5. Seat belts, and the buses on which they are installed, will be in operation for 15 years (n).

6. Seat belts can be installed at a cost of $990 per bus ($I = \$990$).

7. Seat belts can be maintained at a cost of $33 per bus per year ($M = \$33$).

8. Interest rate (i) is 0.05.

9. Seat belts have no salvage value at the end of 15 years.

Solution

$$X = \frac{1{,}000{,}000}{I\left[\dfrac{i\,(1+i)^n}{(1+i)^n - 1}\right] + M}$$

$$= 7{,}789 \text{ buses}$$

where

X = number of school ouses that could be equipped and maintained with seat belts for an investment of $1 million/year,
I = installation cost per bus,
i = interest rate,
n = service life of seat belts (15 years), and
M = maintenance cost per bus.

The initial cost to install seat belts on 7,789 bu es is $7,711,110 (7,789 buses at $990 per bus). The sum of $7,711,110 can be recovered in 15 years (with an interest rate of 5 percent) at $742,950/year:

$$\$742{,}950 = \$7{,}711{,}110\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right]$$

(The bracketed term on the right side of the equation is referred to as a capital recovery factor.)

The cost to maintain seat belts on 7,789 buses at \$33 per bus is \$257,050/year. Or the *annual cost* of installing and maintaining seat belts on 7,789 buses is \$1 million.

If there are 331,500 school buses in the nation's fleet of large school buses that are not equipped with seat belts, and if 10 passenger fatalities per year occur on these buses, then 2.3 percent (7,789/331,500) of these fatalities (i.e., 0.23 fatalities) might be expected to occur on belt-equipped buses if seat belts are ineffective. But, if the seat belt use rate is 50 percent ($U = 0.50$), and if belts reduce the likelihood of death by 20 percent ($R = 0.20$), seat belts could be expected to save 0.023 life per year. Or,

$$Y = FURX/S$$

$$= 0.023 \text{ fatality}$$

where

Y = number of lives saved and injuries reduced for an investment of \$1 million/year,
F = number of passengers killed,
U = number of passengers using seat belts,
R = likely reduction of death and injuries, and
S = buses with GVWRs greater than 10,000 lb not equipped with seat belts.

By substituting A, B, or C for F in the second equation, expected reductions in A-, B- or C-level injuries may be calculated:

$$Y = AURX/S$$

$$= 1.12 \text{ A-level injuries}$$

$$Y = BURX/S$$

$$= 5.58 \text{ B-level injuries}$$

$$Y = CURX/S$$

$$= 15.62 \text{ C-level injuries}$$

Higher Seat Backs

Questions

1. How many school buses (X) could be equipped and maintained with higher seat backs for an investment of $1 million/year?
2. How many lives would be saved (Y) and how many injuries would be reduced each year by this investment?

Assumptions

1. There are 390,000 school buses in the United States (S = 390,000).
2. On average, 12 students are killed as school bus passengers each year (F = 12). Another 475 receive A-level injuries (A = 475), 2 375 receive B-level injuries (B = 2,375), and 6,650 receive C-level injuries (C = 6,650).
3. Higher seat backs will reduce student pedestrian casualties (fatalities and A-, B-, and C-level injuries) by up to 20 percent (R = 0.20).
4. Higher seat backs, and the buses on which they are installed, will be in operation for 15 years (n).
5. Higher seat backs can be installed at an added cost of $150 per bus ($I$ = $150).
6. Higher seat backs can be maintained at no added cost (M = $0).
7. Interest rate (i) is 0.05.
8. Higher seat backs have no salvage value at the end of 15 years.

Solution

$$X = \frac{1{,}000{,}000}{I\left[\dfrac{i\,(1+i)^n}{(1+i)^n - 1}\right] + M}$$

$$= 69{,}198 \text{ buses}$$

where X is the number of buses that could be equipped and maintained with higher seat backs for an investment of $1 million/year.

$$Y = FRX/S$$

$$= 0.426 \text{ fatality}$$

By substituting A, B, or C for F in the second equation, expected reductions in A-, B-, or C-level injuries may be calculated:

$Y = ARX/S$

$= 16.85$ A-level injuries

$Y = BRX/S$

$= 84.28$ B-level injuries

$Y = CRX/S$

$= 235.97$ C-level injuries

School Bus Monitors

Questions

1. How many school buses (X) could be staffed by adult monitors for an investment of \$1 million/year?
2. How many lives would be saved (Y) and how many injuries would be reduced each year by this investment?

Assumptions

1. There are 390,000 school buses in the United States ($S = 390{,}000$).
2. On average, 50 students (12 school bus passengers and 38 pedestrians in loading zones) are killed in school bus accidents each year. Including students inside and outside the bus, another 637 receive A-level injuries ($A = 637$), 2,618 receive B-level injuries ($B = 2{,}618$), and 7,053 receive C-level injuries ($C = 6{,}312$).
3. School bus monitors can be hired at \$5.40/hr, 5 hr/day, 180 days/year. Or, school bus monitors cost \$4,860 per bus per year ($M = \$4{,}860$).
4. School bus monitors will reduce school bus accident casualties (fatalities and A-, B-, and C-level injuries) by up to 75 percent ($R = 0.75$).

Solution

$X = 1{,}000{,}000/M$

$= 206$ monitored school buses

where X is the number of buses that could be staffed with school bus monitors for an investment of $1 million/year.

$Y = FRX/S$

$= 0.020$ fatality

By substituting A, B, or C for F in the second equation, expected reductions in A-, B-, or C-level injuries may be calculated:

$Y = ARX/S$

$= 0.26$ A-level injury

$Y = BRX/S$

$= 1.04$ B-level injuries

$Y = CRX/S$

$= 2.79$ C-level injuries

Crossing Control Arms

Questions

1. How many school buses (X) could be equipped and maintained with crossing control arms for an investment of $1 million/year?
2. How many lives would be saved (Y) and how many injuries would be reduced each year by this investment?

Assumptions

1. There are 390,000 school buses in the United States ($S = 390{,}000$).
2. On average, 24 students are struck and killed by school buses each year. Two-thirds of those killed by school buses are struck by the front of the bus

(F = 16). Another 37 receive A-level injuries (A = 37), 57 receive B-level injuries (B = 57), and 95 receive C-level injuries (C = 95).

3. Crossing control arms will reduce student pedestrian casualties (fatalities and A-, B-, and C-level injuries) by up to 25 percent (R = 0.25).

4. Crossing control arms, and the buses on which they are installed, will be in operation for 15 years (n).

5. Crossing control arms can be installed for $200 per bus ($I$ = $200).

6. Crossing control arms can be maintained at a cost of $20 per bus per year ($M$ = $20).

7. Interest rate (i) is 0.05.

8. Crossing control arms have no salvage value at the end of 15 years.

Solution

$$X = \frac{1{,}000{,}000}{I\left[\dfrac{i\,(1+i)^n}{(1+i)^n - 1}\right] + M}$$

$$= 25{,}466 \text{ buses}$$

where X is the number of buses that could be equipped and maintained with crossing control arms for an investment of $1 million/year.

$$Y = FRX/S$$

$$= 0.261 \text{ fatality}$$

By substituting A, B, or C for F in the second equation, expected reductions in A-, B-, or C-level injuries may be calculated:

$$Y = ARX/S$$

$$= 0.61 \text{ A-level injury}$$

$$Y = BRX/S$$

$$= 0.93 \text{ B-level injury}$$

$Y = CRX/S$

$= 1.55$ C-level injuries

Electronic Sensors

Questions

1. How many school buses (X) could be equipped and maintained with electronic sensors for an investment of $1 million/year?
2. How many lives would be saved (Y) and how many injuries would be reduced each year by this investment?

Assumptions

1. There are 390,000 school buses in the United States (S = 390,000).
2. On average 24 student pedestrians are killed by school buses in loading zones each year (F = 24). Another 57 receive A-level injuries (A = 57), 85 receive B-level injuries (B = 85), and 141 receive C-level injuries (C = 141).
3. Electronic sensors will reduce student pedestrian casualties (fatalities and A-, B-, and C-level injuries) by up to 50 percent (R = 0.50).
4. Electronic sensors, and the buses on which they are installed, will be in operation for 15 years (n).
5. Electronic sensors can be installed for $1,600 per bus ($I$ = $1,600).
6. Electronic sensors can be maintained at a cost of $80 per bus per year ($M$ = $80).
7. Interest rate (i) is 0.05.
8. Electronic sensors have no salvage value at the end of 15 years.

Solution

$$X = \frac{1{,}000{,}000}{I\left[\dfrac{i\,(1+i)^n}{(1+i)^n - 1}\right] + M}$$

$= 4{,}271$ buses

where X is the number of buses that could be equipped and maintained with electronic sensors for an investment of \$1 million/year.

$$Y = FRX/S$$
$$= 0.131 \text{ fatality}$$

By substituting A, B, or C for F in the second equation, expected reductions in A-, B-, or C-level injuries may be calculated:

$$Y = ARX/S$$
$$= 0.32 \text{ A-level injury}$$

$$Y = BRX/S$$
$$= 0.46 \text{ B-level injury}$$

$$Y = CRX/S$$
$$= 0.78 \text{ C-level injury}$$

Mechanical Sensors

Questions

1. How many school buses (X) could be equipped and maintained with mechanical sensors for an investment of \$1 million/year?
2. How many lives would be saved (Y) and how many injuries would be reduced each year by this investment?

Assumptions

1. There are 390,000 school buses in the United States (S = 390,000).
2. On average 24 student pedestrians are killed by school buses in loading zones each year (F = 24). Another 57 receive A-level injuries (A = 57). 85 receive B-level injuries (B = 85), and 141 receive C-level injuries (C = 141).
3. Mechanical sensors will reduce student pedestrian casualties (fatalities and A, B, and C-level injuries) by up to 50 percent (R = 0.50).
4. Mechanical sensors, and the buses on which they are installed, will be in operation for 15 years (n).

5. Mechanical sensors can be installed for $2,295 per bus ($I$ = $2,295).

6. Mechanical sensors can be maintained at a cost of $115 per bus per year ($M$ = $115).

7. Interest rate (i) is 0.05.

8. Mechanical sensors have no salvage value at the end of 15 years.

Solution

$$X = \frac{1{,}000{,}000}{I\left[\frac{i\,(1+i)^n}{(1+i)^n - 1}\right] + M}$$

$$= 2{,}975 \text{ buses}$$

where X is the number of buses that could be equipped and maintained with mechanical sensors for an investment of $1 million/year.

$$Y = FRX/S$$

$$= 0.092 \text{ fatality}$$

By substituting A, B, or C for F in the second equation, expected reductions in A-, B-, or C-level injuries may be calculated:

$$Y = ARX/S$$

$$= 0.22 \text{ A-level injury}$$

$$Y = BRX/S$$

$$= 0.32 \text{ B-level injury}$$

$$Y = CRX/S$$

$$= 0.53 \text{ C-level injury}$$

Stop Signal Arms

Questions

1. How many school buses (X) could be equipped and maintained with stop signal arms for an investment of $1 million/year?

2. How many lives would be saved (Y) and how many injuries would be reduced each year by this investment?

Assumptions

1. There are 390,000 school buses in the United States; 44 percent of them (i.e., 171,600), may not be equipped with stop signal arms[1] (S = 171,600).
2. On average, 5 students are struck and killed in school bus loading zones each year by vehicles other than school buses (F = 5). Another 46 receive A-level injuries (A = 46), 70 receive B-level injuries (B = 70), and 115 receive C-level injuries (C = 115).[2]
3. Stop signal arms will reduce student pedestrian casualties (fatalities and A-, B-, and C-level injuries) by 30 percent (R = 0.30).
4. Stop signal arms, and the buses on which they are installed, will be in operation for 15 years (n).
5. Stop signal arms can be installed for \$200 per bus (I = \$200).
6. Stop signal arms can be maintained at a cost of \$10 per bus per year (M = \$10).
7. Interest rate (i) is 0.05.
8. Stop signal arms have no salvage value at the end of 15 years.

Solution

$$X = \frac{1{,}000{,}000}{I\left[\dfrac{i\,(1+i)^n}{(1+i)^n - 1}\right] + M}$$

$$= 34{,}166 \text{ buses}$$

where X is the number of buses that could be equipped and maintained with stop signal arms for an investment of \$1 million/year.

$$Y = FRX/S$$

$$= 0.299 \text{ fatality}$$

By substituting A, B, or C for F in the second equation, expected reductions in A-, B-, or C-level injuries may be calculated:

$Y = ARX/S$

$= 2.75$ A-level injuries

$Y = BRX/S$

$= 4.19$ B-level injuries

$Y = CRX/S$

$= 6.88$ C-level injuries

External Loud Speaker Systems

Questions

1. How many school buses (X) could be equipped and maintained with external loud speaker systems for an investment of $1 million/year?
2. How many lives would be saved (Y) and how many injuries would be reduced each year by this investment?

Assumptions

1. There are 390,000 school buses in the United States (S = 390,000).
2. On average, 12 students are struck and killed in school bus loading zones each year by vehicles other than school buses (F = 12). Another 105 receive A-level injuries (A = 105), 158 receive B-level injuries (B = 158), and 262 receive C-level injuries (C = 262).
3. External loud speaker systems will reduce student pedestrian casualties (fatalities and A-, B-, and C-level injuries) by 20 percent (R = 0.20).
4. External loud speaker systems, and the buses on which they are installed, will be in operation for 15 years (n).
5. External loud speaker systems can be installed for $200 per bus ($I$ = $200).
6. External loud speaker systems can be maintained at a cost of $10 per bus per year ($M$ = $10).
7. Interest rate (i) is 0.05.
8. External loud speaker systems have no salvage value at the end of 15 years.

Solution

$$X = \frac{1{,}000{,}000}{I\left[\dfrac{i\,(1+i)^n}{(1+i)^n - 1}\right] + M}$$

$$= 34{,}166 \text{ buses}$$

where X is the number of buses that could be equipped with external loud speakers for an investment of \$1 million/year.

$$Y = FRX/S$$

$$= 0.210 \text{ fatality}$$

By substituting A, B, or C for F in the second equation, expected reductions in A-, B-, or C-level injuries may be calculated:

$$Y = ARX/S$$

$$= 1.84 \text{ A-level injuries}$$

$$Y = BRX/S$$

$$= 2.77 \text{ B-level injuries}$$

$$Y = CRX/S$$

$$= 4.59 \text{ C-level injuries}$$

Pupil Education Programs (Grades K through 6)

Questions

1. How many children (X) could attend a pedestrian safety education program for an investment of \$1 million/year?
2. How many lives would be saved (Y) and how many injuries would be reduced each year by this investment?

Assumptions

1. There are 25,000,000 pupils transported by school bus in the United States; 54 percent (i.e., 7/13) are in grades K through 6 (P = 13,500,000).
2. On average, 31 of these pupils are in grades K through 6 and are killed as pedestrians in loading zones each year (F = 31). Another 139 receive A-level injuries (A = 139), 209 receive B-level injuries (B = 209), and 347 receive C-level injuries (C = 347).
3. The cost of the pupil pedestrian education program is $1.00 per pupil ($E$ = $1.00).
4. Pupil education programs will reduce student pedestrian casualties (fatalities and A-, B-, and C-level injuries) by 20 percent (R = 0.20).

Solution

X = 1,000,000/E

= 1,000,000 students

where X is the number of children that could attend a pedestrian safety education program for an investment of $1 million/year and E is the cost of pedestrian education programs.

$Y = FRX/P$

= 0.459 fatality

where P is the number of pupils transported by bus in grades K through 6.

By substituting A, B, or C for F in the second equation, expected reductions in A-, B-, or C-level injuries may be calculated:

$Y = ARX/P$

= 2.06 A-level injuries

$Y = BRX/P$

= 3.10 B-level injuries

$$Y = CRX/P$$

$$= 5.14 \text{ C-level injuries}$$

Notes

1. Twenty-two (44 percent) states do not require stop signal arms on newly purchased school buses.
2. The number of deaths and injuries given in the second assumption is 44 percent of national totals because stop signal arms are not required in 22 (44 percent) states.

Study Committee Biographical Information

Charley V. Wootan, *Chairman,* is Director of the Texas Transportation Institute, College Station. He received his B.S., M.S., and Ph.D. from Texas A&M University. Dr. Wootan headed the Transportation Economics and Planning Division of the Texas Transportation Institute at Texas A&M University from 1961 to 1974 and served as Associate Director and Research Economist from 1965 to 1976. Long active in TRB activities, Dr. Wootan is a former Chairman of the Executive Committee and currently serves on the TRB Executive Committee Subcommittee on Planning and Policy Review and is Chairman of the Division A (Technical Activities) Council of TRB.

Phyllis F. Agran, a pediatrician and researcher in the field on injury control, is an Associate Professor at the University of California, Irvine, School of Medicine. Dr. Agran received her B.A. and a Secondary Teaching Credential from the University of California, Berkeley, an M.A. from Boston University, and her M.D. from the University of California, Irvine. She also holds an M.P.H. from the Harvard University School of Public Health.

R. Don Blim is a pediatrician and President of Pediatric Associates, Kansas City, Missouri. He is currently Assistant Clinical Professor at the University of Kansas School of Medicine. In private practice for 33 years, Dr. Blim is Past President of the American Academy of Pediatrics and a member of the Council, National Institute of Child Health and Human Development and the Institute of Medicine.

B. J. Campbell is Director of the Highway Safety Research Center at the University of North Carolina, Chapel Hill. He received his B.A. and M.A. from Texas Christian University and his Ph.D. from the University of North Carolina. Dr. Campbell served first as Research Associate and later as Assistant Director in the Institute of Government at the University of North

Carolina. Later at Cornell University, he held the positions of Assistant Director of Automotive Crash Injury Research and Head of the Accident Research Branch at the Cornell Aeronautical Laboratory.

Ernest Farmer is Director of Pupil Transportation for the Tennessee State Department of Education in Nashville. He received his B.S. and M.S. from Middle Tennessee State University and his Ed.D. in education administration and supervision from the University of Tennessee. Dr. Farmer joined the State Department of Education in 1955 and assumed his pupil transportation responsibilities in 1958.

John D. Graham is Deputy Director of the New England Injury Prevention Research Center at the Harvard School of Public Health, Boston, Massachusetts. He received his B.A. from Wake Forest University, his M.A. from Duke University, and his Ph.D. from Carnegie-Mellon University. Among the positions Dr. Graham has held are Senior Staff Associate for the Committee on Risk and Decision Making at the National Research Council and Project Manager of the Unregulated Mobile Source Emissions of the Health Effects Institute. He is currently Associate Professor of Policy and Decision Sciences at the Harvard School of Public Health.

Craig Marks is Vice President, Technology and Productivity Planning for Allied-Signal, Inc., Southfield, Michigan. He holds a B.S., M.S., and Ph.D. in mechanical engineering from the California Institute of Technology. Before joining Allied-Signal, he was Vice President, Technology for TRW Safety Restraint Systems and just before that, Vice President, Engineering and Technology for the TRW Automotive Sector. Previously, he held various positions on the Engineering Staff of General Motors Corporation, including Executive Director for the Vice President of Engineering. He also served as Executive Director of the GM Environmental Activities Staff. Dr. Marks is a member of the National Academy of Engineering, the Industrial Research Institute, and the American Society of Mechanical Engineers (ASME), and is on the ASME Industry Advisory Committee. He also presently serves on the Society of Automotive Engineers (SAE) Board of Directors and on several SAE committees.

Kyle E. Martin is Senior Vice President of Sales and Operations for Mayflower Contract Services, Inc., Shawnee Mission, Kansas. A graduate of the United States Naval Academy, he received his M.S. from the University of Southern California and an M.B.A. from Rockhurst College. Mr. Martin served in the United States Navy from 1970 to 1980 as a naval aviator and as an instructor at the Naval Fighter Weapons School (Top Gun). Mr. Martin entered the transportation industry in 1980, joining R. W. Harmon & Sons, Inc., as systems manager and later as Director of Operations.

Malcolm B. Mathieson is Vice President of Engineering for Thomas Built Buses, Inc., High Point, North Carolina. After graduating from the University of Alabama with a B.S. in mechanical engineering, he joined Pratt and Whitney Aircraft as an Experimental Engineer at their Connecticut plant, later transferring to their Florida Research and Development Center, where he became an Assistant Project Engineer in the Applied Research Department. Mr. Mathieson later joined the General Electric Company Small Gas Turbine Group in Lynn, Massachusetts, where he became Manager of T64 Systems Analysis. He joined Thomas Built Buses, Inc., in 1976 as Engineering Manager and later became Corporate Director of Engineering before assuming his current position as Vice President. Mr. Mathieson is a member of Pi Tau Sigma honorary engineering fraternity, the National Society of Professional Engineers, and the Society of Automotive Engineers, where he serves on the Technical Board's Safety Advisory Committee.

James L. Pline, a civil engineer, retired in 1987 and is currently working part-time as an engineering consultant. He received his B.S. in civil engineering from the University of Idaho and an M.A. in public administration from Boise State University. He also holds a certificate in traffic engineering from Yale University. Before his retirement, Mr. Pline held several positions with the Idaho Transportation Department. Currently, he is International President of the Institute of Transportation Engineers and Vice Chairman of the National Committee on Uniform Traffic Control Devices. He is a long-term member of the Idaho Traffic Safety Commission and has authored and presented numerous articles on traffic engineering and highway safety. Mr. Pline recently represented the United States at the International Congress on Ways and Means to Improve Highway Safety in Tel Aviv, Israel.

David F. Preusser is a Principal Associate with Dunlap and Associates, Inc., Norwalk, Connecticut. He received his Ph.D. in experimental psychology from Yale University in 1971. Dr. Preusser's research interests are in highway safety, pedestrian safety, and the evaluation of training and education programs. He has studied alcohol and driving, driver rehabilitation, teenage driving, and pedestrian safety programs for children. More recently, he directed a nationwide transportation needs survey of teenagers, studied the impact of mandatory seat belt use legislation, and directed an assessment of drug use among truck drivers. Dr. Preusser has served as an Adjunct Associate Professor at Columbia University and has authored or coauthored more than

40 research reports in highway safety. He is currently a technical adviser to the Pedestrian Safety Committee of the National Safety Council.

David C. Viano is Principal Research Scientist in the Biomedical Science Department of General Motors Research Laboratories, Warren, Michigan. He has a B.S. in electrical engineering from Santa Clara University, an M.S. and Ph.D. in applied mechanics from the California Institute of Technology, and has completed postdoctoral research in biomedical sciences. At General Motors Research Laboratories he is in charge of the research program that deals with the biomechanics and pathophysiology of automotive-crash injuries. Dr. Viano is a specialist in the biomechanics of whole-body, internal-organ, and soft-tissue injury and has identified mechanisms of soft-tissue damage. He is also experienced in the evaluation of crash protection systems and occupant restraints. He serves on the adjunct faculty at Wayne State University, where he has taught graduate courses in biomechanics and conducted research. He served on the NRC Committee on Trauma Research, which wrote *Injury in America and Injury Control*, and is a member of the Centers for Disease Control INPRESS committee.

Kathleen Weber is a Senior Research Associate, University of Michigan Medical School, Section of Pediatric Surgery, Ann Arbor. She is responsible for the direction of various research projects on child passenger protection, including dynamic testing of child restraint systems. After receiving her B.A. in English and M.A. in library science from the University of Wisconsin, Ms. Weber joined the University of Michigan Transportation Research Institute as Assistant Librarian and later became Head Librarian. In 1979 she joined the research staff to study child restraint convenience and later became involved in crash testing and dummy development. She is a member of the Association for the Advancement of Automotive Medicine and the Society of Automotive Engineers' Children's Restraint Systems Task Force. She has coauthored and edited several reports and publications on human response and tolerance to impact.

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